Special Protection Area Program Annual Report 2007

Prepared by the Montgomery County Department of Environmental Protection in Cooperation With the Department of Permitting Services and the Maryland-National Capital Park and Planning Commission

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In Memory of
Councilmember Marilyn Praisner

"Marilyn Praisner was instrumental in the creation and implementation of the Special Protection Area program. She supported the use of the best available environmental information in balancing the costs and benefits of land use decisions. Ms. Praisner was a dedicated public servant and strong advocate for the conservation of natural resources and management of these natural resources for future generations."

Bob Hoyt

Montgomery County Department of Environmental Protection
Bob Hoyt, Director

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Table of Contents

Executive Summary E-1
Introduction E-1
BMP Monitoring E-1
Biological Monitoring E-2
Landscape Changes and LiDAR Imagery E-2
Recommendations E-3
1. Introduction 1-1
1.1 Purpose 1-1
1.2 Background 1-1
1.2.1 SPA Program 1-1
1.2.2 BMP Monitoring 1-2
1.2.3 Clarksburg Master Plan and Stage 4 Triggers 1-3
1.3 BMP Monitoring Status 1-6
1.4 Clarksburg Monitoring Partnership 1-6
1.5 Streams and Imperviousness 1-9
1.6 Development and Imperviousness 1-13
1.7 Landscape Changes and Streams 1-13
1.8 Environmental Site Design 1-14
2. SPA Water Quality Review Plan and BMP Monitoring Review Process 2-1
2.1 Water Quality Plan Review Process 2-1
2.2 BMP Monitoring Review Process 2-2
2.3 SPA BMP Technology 2-3
2.3.1 Sediment and Erosion Control (During Construction) 2-3
2.3.2 Stormwater Management (Post Construction) 2-3
3. BMP Effectiveness 3-1
3.1 Water Quality Monitoring 3-2
3.1.1 Stream Temperature 3-2
3.1.2 Embeddedness 3-3
3.1.3 Groundwater Levels 3-3
3.1.4 Groundwater Chemistry 3-3
3.1.5 Instream Chemistry 3-5
3.1.6 Continuous Stream Flow 3-5
3.2 Sediment and Erosion Control (S&EC) BMP Monitoring 3-5
3.2.1 Grab Samples 3-5
3.2.2 Flow-weighted Composite TSS Sampling 3-8
Sediment Basin #3 Clarksburg Town Center (Clarksburg SPA) 3-9
Sediment Basin #2 Gateway Commons (Clarksburg SPA) 3-10
Other Projects 3-11
3.3 Stormwater Management (SWM) BMP Monitoring 3-12
3.3.1 Surface Sand Filter 3-12
Background 3-12
Willow Oaks (Piney Branch SPA) 3-13
Snider's Estates (Upper Paint Branch SPA) 3-14

3.3.2 Stormceptor® Results 3-15
Background 3-15
Cloverly Safeway (Upper Paint Branch SPA) 3-15
3.4 Discussion of Structural Monitoring of S&EC and SWM BMPs 3-18
4. Stream Characteristics 4-1
4.1 Landscape Changes in the Newcut Road area of Clarksburg 4-1
4.2 Hydrology 4-8
4.2.1 Background 4-8
4.2.2 Study Design and Data Collection 4-8
4.2.3 Hydrologic Data Analysis and Interpretation 4-9
4.3 Changes in Stream Geomorphology 4-13
4.3.1 Study Design and Data Collection 4-14
4.3.2 Data Analysis and interpretation 4-14
4.4 Changes in Physical Chemistry 4-20
4.4.1 Water temperature (Clarksburg and Paint Branch) 4-20
4.5 Water Quality 4-21
4.6 Habitat 4-21
5. Biological Integrity 5-1
5.1 Biological Stream Monitoring 5-1
5.2 Stream Condition Comparison 5-3
5.3 Benthic Macroinvertebrate IBI Score Comparison 5-7
5.3.1 Clarksburg 5-8
5.3.2 Ten Mile Creek 5-9
5.3.3 Piney Branch SPA 5-9
5.3.4 Upper Paint Branch SPA 5-9
5.3.5 Upper Rock Creek SPA 5-11
5.4 Changes in Benthic Macroinvertebrate Community Structure and Function 5-12
5.4.1 Introduction 5-12
5.4.2 Changes in Community Structure and Function 5-12
5.4.3 Future stream conditions and potential for recovery 5-13
6. Summary/ Results 6-1
6.1 Land Development 6-1
6.2 Imperviousness 6-1
6.3 Stream Hydrology 6-2
6.4 Stream Morphology 6-2
6.5 Water Chemistry 6-2
6.6 BMP Efficiency 6-3
6.6.1 Sediment and Erosion Control 6-3
6.6.2 Stormwater Management 6-3
6.7 Biological Integrity 6-3
6.8 Condition of Ten Mile Creek 6-4
7. Conclusions and Recommendations 7-1
7.1 Water Quality Review Process 7-1
7.2 BMP Water Quality Monitoring Process 7-1
7.3 Sediment and Erosion Control Improvements 7-1

7.4 Methods, Facilities and Practices Being Utilized by Applicants as Part of the Water Quality Review Process 7-1
8. Literature Cited 8-1
9. Glossary 9-1

Technical Appendices (located in separate documents)

Technical Appendix for Section 3: BMP Effectiveness
Technical Appendix for Section 4: Stream Characteristics
Technical Appendix for Section 5: Biology

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List of Figures

Figure 1.1. Location of Special Protection Areas in Montgomery County. 1-2
Figure 1.2. The Four Development Stages in the Clarksburg Master Plan Area............ 1-4
Figure 1.3. Location of the Clarksburg Monitoring Partnership BACI Three Test Areas and Two Controls Areas. 1-8
Figure 1.4. The Reformulated Impervious Cover Model 1-10
Figure 1.5. Preliminary Relationship Between Imperviousness and Stream Condition Ratings in Montgomery County, MD (MCDEP 2003)... 1-12
Figure 3.1. Monitoring Locations 3-1
Figure 3.2. SPA BMP Monitoring Project Status in 2007... 3-2
Figure 3.3. Briarcliff Manor West (Upper Paint Branch SPA) Groundwater Monitoring. 3-4
Figure 3.4. USGS (Fairland in Upper Paint Branch SPA) Groundwater Monitoring. 3-4
Figure 3.5. Forebay (Inlet) and Outfall TSS Concentrations (grab sample data). 3-6
Figure 3.6. Percent Difference in Forebay and Outfall TSS Concentrations Where Forebay TSS Values are Greater or Equal to 100 mg/L (grab sample data). 3-7
Figure 3.7. Percent Difference in Forebay and Outlet TSS Concentrations Where Forebay TSS Values are Less Than 100 mg/L (grab sample data)......................... 3-7
Figure 3.8. Cloverly Safeway Stormceptor Loads.. 3-17
Figure 4.1. 2002 LiDAR Imagery of Newcut Road Neighborhood, Greenway Village, and Clarksburg Village (U.S. EPA LEB). 4-3
Figure 4.2. 2004 LiDAR Imagery of Newcut Road Neighborhood, Greenway Village, and Clarksburg Village (U.S. EPA LEB). 4-4
Figure 4.3. 2007 LiDAR Imagery of Newcut Road Neighborhood, Greenway Village, and Clarksburg Village (U.S. EPA LEB). 4-5
Figure 4.4. Total Cut and Fill Differences for the Newcut Road Neighborhood, Greenway Village, and Clarksburg Village between years 2002 & 2007 4-7
(U.S. EPA LEB)... 4-7
Figure 4.5. Annual Flow (adjusted for drainage area). 4-11
Figure 4.6. Comparison of Stream Response to Storm Events: 2004 to 2007.............. 4-12
Figure 4.7. Stream channel changes as a result of development and increases in imperviousness (Paul and Meyer 2001)... 4-13
Figure 4.8. Location of the Clarksburg Monitoring Partnership BACI three test areas and two control areas. Also included are biological monitoring stations and geomorphic survey locations.. 4-16
Figure 4.9. Little Seneca 104 tributary (Newcut Road neighborhood) geomorphology survey test areas (A), Little Bennett Creek survey control areas (B), and Germantown negative control survey areas (C)... 4-17
Figure 4.10. Representative cross sections from Newcut Road Neighborhood, Little Seneca 104 Tributary test location, Area 4. Cross sections are both measured in Riffle/run features. 4-18
Figure 4.11. Representative cross sections from Little Bennett Creek, Sopers Branch control location, Area 4. Cross sections both measured in Riffle/run features...... 4-19

Figure 4.12. Representative cross sections from Germantown (Crystal Rock) pre-2000 control location, Area 2. Cross section 1 measured in a Riffle/run feature. 4-20
Figure 5.1. Pre-development (1994-1998)) stream conditions (average of fish and benthic % IBI scores) in the Clarksburg SPA. 5-3
Figure 5.2. Current (2006 & 2007) stream conditions (average of fish and benthic % IBI scores) in the Clarksburg SPA. 5-4
Figure 5.3. Pre-development (1994-1998) stream conditions (average of fish and benthic % IBI scores) in the Paint Branch SPA. 5-5
Figure 5.4. Current (2006 & 2007) stream conditions (average of fish and benthic % IBI scores) in the Paint Branch SPA. Stations PBGS102A, PBGS102B, PBGH202, PBAT101, and PBFF101 were not monitored in recent years due to monitoring priorities in other SPAs, so their drainage areas were absorbed by downstream active stations. 5-5
Figure 5.5. Pre-development (1995-1997) stream conditions (average of fish and benthic % IBI scores) in the Piney Branch SPA. 5-6
Figure 5.6. Current (2006 & 2007) stream conditions (average of fish and benthic % IBI scores) in the Piney Branch SPA. 5-6
Figure 5.3. Median Benthic IBI Scores for Clarksburg Control and Test Areas. 5-8
Figure 5.4. Median benthic macroinvertebrate IBI scores for Piney Branch control and test areas. 5-10
Figure 5.5. Median benthic IBI scores for Upper Paint Branch control and test areas. 5-10
Figure 5.6. Median benthic IBI scores for Upper Rock Creek control and test areas. 5-11

List of Tables

Table 3.1. Sediment loadings: Clarksburg Town Center Phase II-B Sediment Basin #3. 3-9

Table 3.2. Total suspended solids loadings and percent difference observed during extended sampling: Clarksburg Town Center Phase II-B Sediment Basin #3. 3-10

Table 3.3. Sediment Loadings: Gateway Commons Sediment Basin #2. 3-11

Table 3.4. Sediment Loadings: Stringtown Rd. Extension Sediment Basin #3. 3-11

Table 3.5. Willow Oaks BMP Pollutant Load Reductions. Load reductions were calculated by examining the total load entering the system (two sand filters in series) with the total load leaving. 3-13

Table 3.6. Storm event data for the five storms used to evaluate Willow Oaks BMP pollutant load reductions efficiency. 3-14

Table 3.7. TR-20 measured storm results for peak flow at Snider's Estates SWM pond 1 outfall. 3-15

Table 3.8. Cloverly Safeway Stormceptor TSS loadings for recent storm events. No storm data is available for analysis. 3-17

Table 4.1. Descriptions of the Five Stream Gages in the Clarksburg Study Area. 4-9

Table 4.2. Sinuosity indices for Newcut Road Little Seneca 104 tributary test area, Little Bennett Soper's Branch control area, and Germantown Crystal Rock control area. Data is shown for furthest downstream areas within each test and control. 4-20

Table 5.1. Control and Test Stations 5-7

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Executive Summary

Introduction

The Special Protection Area (SPA) program was initiated in 1994 by County law. According to the Montgomery County Code, Section 19-61(h) a Special Protection Area is defined as:

"a geographic area where:

(1) existing water resources, or other environmental features directly relating to those water resources are of high quality or unusually sensitive; and
(2) proposed land uses would threaten the quality or preservation of those resources or features in the absence of special water quality protection measures which are closely coordinated with appropriate land use controls."

As mandated by County law, this annual report summarizes the monitoring conducted within the four Special Protection Areas: Clarksburg, Paint Branch, Piney Branch, and Upper Rock Creek. In accordance with the Clarksburg Master Plan and Hyattstown Special Study Area Report (Master Plan) (M-NCPPC June 1994), available information regarding water quality results associated with Newcut Road and Town Center development and other similar developments will also be provided. Per the Master Plan, this information will be used to assist the County Council in determining "if the methods, facilities and practices then being utilized by applicants as part of the water quality review process then in place are sufficient to protect the water quality of Ten Mile Creek."

SPA monitoring comprises both monitoring of stream biology and monitoring to evaluate how well best management practices (BMPs) are removing pollutants (such as sediment, a primary pollutant from construction sites). Water quality is measured using biological indicators, specifically the range and condition of macroinvertebrates (insect larvae) and fish that are living in the stream. The survival of more sensitive species indicates better water quality. Biological monitoring does not measure specific pollutant loads and the results are not indicators of human health. The preliminary results indicate that BMPs are performing well, in some cases better than expected. However, biological monitoring indicates varying degrees of degradation in the streams.

BMP Monitoring

Best management practices are defined as techniques that are effective in eliminating or reducing the amount of pollution or other detrimental impacts to a watershed or wetland (Montgomery County Code 19-61(a)). The BMPs discussed in this report are structural techniques and include sand filters, detention ponds, and bio-retention cells. Initial monitoring focused on the effects of urbanization on stream water quality and monitored the stream for conditions like embeddedness (indicated by sediment settling), and water temperature. More recently and at present, monitoring focuses on the ability of a BMP to remove a contaminant and evaluates percent removal of contaminants (removal efficiency), with a focus on sediment.

The Clarksburg SPA provides a unique opportunity to evaluate the effectiveness of BMPs. Whereas most other areas in the County were already developed and had already-impaired stream water quality prior to the beginning of SPA monitoring, Clarksburg was rural, undeveloped and had good-to-excellent water quality. Detrimental impacts to the biological health of the streams in Clarksburg have been observed due to: 1) the unexpected downturn in the construction economy and its consequences on the landscape (rapid start of construction followed by delays, leaving large areas of land unstabilized); 2) the fact that most BMPs have not been converted from sediment and erosion control (S&EC) to stormwater management (SWM); and 3) the density of the development.

Biological Monitoring

The water in the small headwater streams monitored for the Upper Rock Creek SPA have consistently been *good* since SPA monitoring began in 2004. No large areas were opened for development in 2007.

The Right Fork of the Upper Paint Branch is where most of the SPA development within Paint Branch has occurred. Post-construction stream conditions are likely to recover to near pre-construction level stream conditions because the benthic community structure remains intact and basically unchanged. This recovery will be monitored after the new stormwater management (SWM) controls are functioning as designed. Brown trout are still present in the Upper Paint Branch SPA. Both the Rock Creek SPA and Paint Branch SPA have an 8% impervious surface cap.

Much of the new SPA development in the upper Piney Branch has occurred since 1998. Benthic conditions in these areas declined to *poor* in 1999 and have remained in the *poor* range since 2003. Stream conditions will be monitored as new developments are completed and SWM controls are functioning as designed.

In Clarksburg, stream conditions were in the *good* to *excellent* range from 1995 to 2002. Construction began in the Clarksburg SPA area in 2002, the same year in which a record drought also occurred throughout the County. The stream conditions in those areas being urbanized and those areas remaining undeveloped diverged in 2003. The stations under construction dropped to a *fair* condition, while the stations without the urban development dropped but remained in the *good* Index of Biological Integrity (IBI) category for benthic macroinvertebrates. In 2007, three brown trout—indicators of good water quality—were discovered in Ten Mile Creek (Stage Four development area). It is not known whether these trout are naturally occurring.

Landscape Changes and LiDAR Imagery

The development process permanently changes the character of the landscape. These changes are cumulative and influence the receiving streams in ways that must be assessed using an indicator of cumulative impact such as biological monitoring. LiDAR (light detection and ranging) imagery has followed the development of the Newcut Road neighborhood of Clarksburg through 2007 (See Section 4.1). The cut-and-fill approach to site development permanently alters the overall topography, natural drainage patterns, and natural infiltration conditions. These changes to the landscape alter hydrology and can permanently affect water quality.

Recommendations

SPAs with more intense development have lower water quality as measured by biological indicators. A variety of controls are recommended to prevent degradation of water quality. Some of these recommendations can be implemented through existing procedures and programs, some through coordination with other departments and agencies, and some through legislative or regulatory changes.

Stormwater management controls, environmental buffers, and other environmentally-sensitive areas should be given a higher priority in land development projects in the SPAs. For example, building lot and road layout is often completed prior to siting stormwater structures. This leads to situations where stormwater structures are placed in an ineffective location immediately adjacent to sensitive stream buffers. Stormwater facilities should be sited before or at least concurrently with the other utilities and infrastructure, not after roads and other major infrastructure are in place.

Presently, BMP monitoring is funded and managed by developers. In the future, developers should be given the option to have the Department of Environmental Protection (DEP) conduct this monitoring for a fee. This would allow for more consistency and reduce some of the problems encountered with monitoring.

In order to minimize the effects of construction on water quality, DEP and the Department of Permitting Services (DPS) will evaluate additional upgrades in sediment and erosion (S&EC) controls in SPAs to further protect water quality during construction. These upgrades will include faster conversions from S&EC structures to permanent SWM structures and stricter, phased stages of construction to allow for greater focus on soil stabilization. Also under consideration are: a grading ordinance to limit the acreage of exposed soils prone to erosion; reduction in the time required for soil stabilization; imposition of stricter utility S&EC; and limits on cut-and-fill activities to retain natural drainage patterns.

Environmental Site Design (ESD) must be the preferred approach to new development in Clarksburg whenever possible, in accordance with the Maryland State Stormwater Management Act (2007). ESD encourages non-structural approaches like grass swales and rain gardens instead of storm drains and underground structures. ESD, including limiting density within sensitive environmental areas through clustering or other mechanisms, should be considered as part of a holistic approach to protecting water quality in Ten Mile Creek.

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1. Introduction
1.1 Purpose

The 2007 Special Protection Area Report is prepared and submitted pursuant to the Montgomery County Code Chapter 19, Article V (*Water Quality Review: Special Protection Areas*), Section 19-67 (2001). The Special Protection Area (SPA) program is implemented through Executive Regulation 29-95: *Water Quality Review for Development in Designated Special Protection Areas*.

As mandated by County law, the Special Protection Area Report summarizes the monitoring conducted in streams and on *Best Management Practice (BMP)* within Special Protection Areas (SPAs). SPA reports are submitted annually to the County Executive and County Council with a copy to the Montgomery County Planning Board.

In accordance with the Clarksburg Master Plan and Hyattstown Special Study Area Report (Master Plan) (M-NCPPC June 1994), available information regarding water quality results associated with Newcut Road and Town Center development and other similar developments will also be provided. Per the Master Plan, this information will be used to assist the County Council in determining "if the methods, facilities and practices then being utilized by applicants as part of the water quality review process then in place are sufficient to protect the water quality of Ten Mile Creek."

1.2 Background

1.2.1 SPA Program

The County Council has designated four areas within Montgomery County as Special Protection Areas (Fig. 1.1). In 1994, The Clarksburg Master Plan approved the creation of the first SPA with the establishment of the Clarksburg Master Plan SPA. In 1995, Piney Branch and Upper Paint Branch were designated as SPAs by separate Council Resolutions. Upper Rock Creek was designated as an SPA on February 24, 2004, with the adoption of the Upper Rock Creek Master Plan. All four SPAs have existing water resources or other environmental features that are of high quality or unusually sensitive. Appropriate *land use* controls and management techniques help ensure that impacts from master planned development activities are mitigated to the greatest extent practicable. Examples of these controls include limiting *imperviousness*, minimizing grading, and protecting natural features such as forested stream buffers as part of land development projects. Special engineered water quality protection measures include *sediment and erosion control (S&EC)* and *stormwater management (SWM)* structures that go beyond current minimum standards.

The SPA program requires the Montgomery County Department of Permitting Services (DPS), the Department of Environmental Protection (DEP), and the Maryland-National Capital Park and Planning Commission (M-NCPPC) to work closely with project developers from the outset of the regulatory review process to minimize impacts to SPA stream conditions. SPA permitting requirements guide the development of concept plans for site imperviousness, site layout, environmental buffers, forest conservation, S&EC, and SWM. Applicant requirements to carry out monitoring are guided by performance goals (Section 2) designed for each development project. Achievement of the performance goals through the site plan design process and accompanying permitting requirements for sediment, erosion, and stormwater management controls requires close

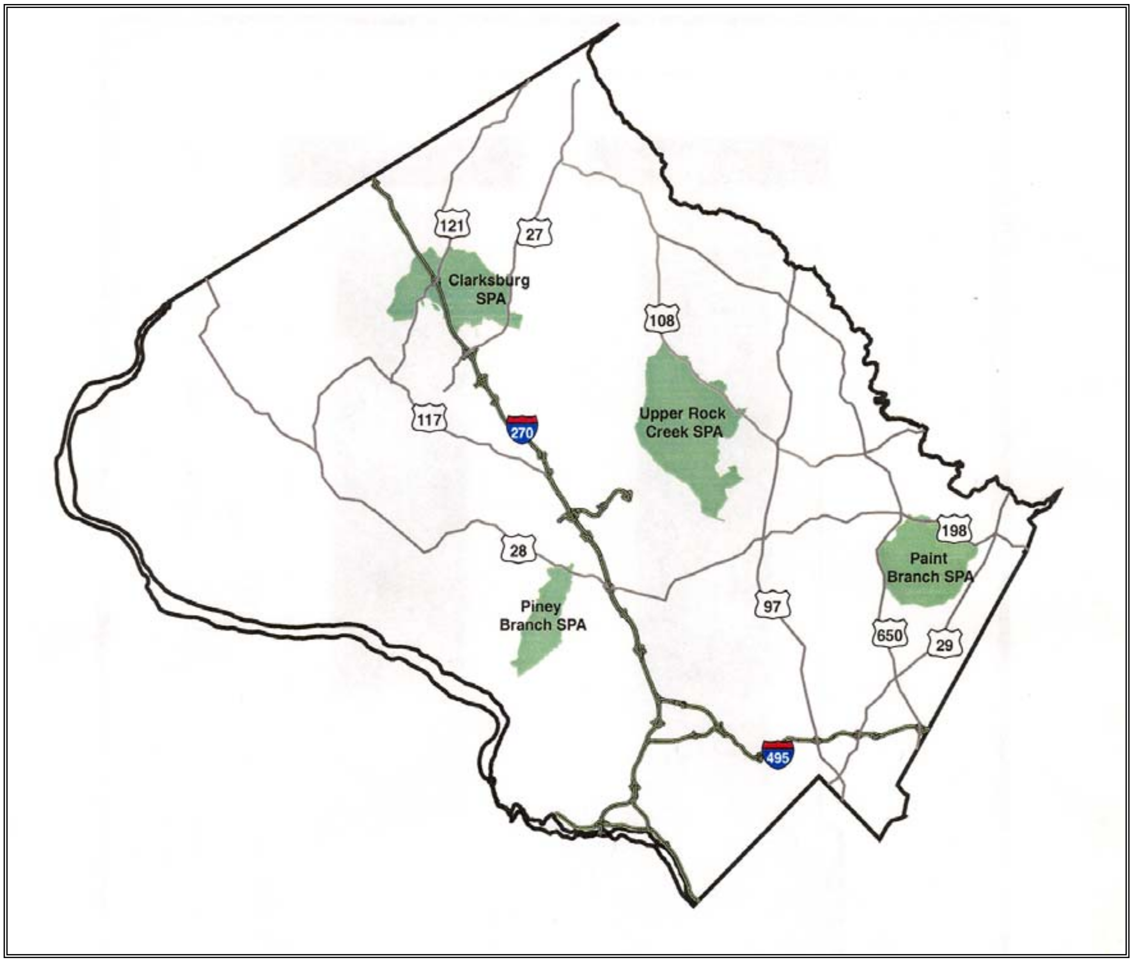


Figure 1.1. Location of Special Protection Areas in Montgomery County.

coordination between the project's design team and environmental, regulatory and planning agencies.

1.2.2 BMP Monitoring

S&EC BMPs are installed on the construction site before initial land disturbing activities begin. S&EC BMPs are designed to capture large volumes of sediment-laden runoff generated during construction. After construction is complete and the site is stabilized, SWM BMPs are installed to attenuate storm flows (quantity control) and capture *pollutants* (quality control). The SPA BMP monitoring program requires developers to monitor selected parameters to evaluate the ability of BMPs to minimize development impacts to the receiving streams. The monitoring data is used to evaluate the design and function of SPA BMPs, link BMP performance to changing stream conditions, and guide future planning decisions. In conjunction with the monitoring performed by the developer, DEP performs watershed wide biological and water quality monitoring to study the overall effects of development on the watershed (Section 5).

During the first six years of the SPA program, BMP monitoring focused on stream-specific water quality parameters (temperature, *sedimentation*, *embeddedness*, and ground water elevation). Starting in 2001, the program shifted to monitoring the pollutant removal efficiencies of structural BMPs. By monitoring pollutant removal efficiencies, the program could evaluate structural BMPs and the functional relationship to treating water quality.

1.2.3 Clarksburg Master Plan and Stage 4 Triggers

The Clarksburg Master Plan (M-NCPPC 1994; hereafter "Master Plan") requires that development occurs in four stages (Fig. 1.2). The Master Plan identifies a set of requirements (triggers) for each development stage that must be met before development can start in that stage. Staging of development is critical for the Clarksburg Planning Area in order to coordinate the timing of development with the provision of public facilities, development of a strong community identity, and the protection of environmentally fragile watersheds. Development in the first three stages is proceeding towards completion.

According to the Master Plan (1994), the triggers that would allow development to proceed in Stage 4, which covers the Ten Mile Creek watershed, are:

1. "Baseline Monitoring: This monitoring will consist of a biological assessment of the aquatic ecosystems and would allow for the comparison of water quality conditions before and after development."

2. "Community Building: at least 2,000 building permits have been issued for housing units in the Newcut Road and Town Center sub-areas of Clarksburg. Stage 4 may begin only after development east of I-270 is underway."

3. "The Eastside BMPs Monitored and Evaluated: The first Annual Report on the Water Quality Review Process (WQRP) following the release of 2,000 building permits in the Newcut Road and Town Center sub-areas is completed by DEP. This report will have evaluated the water quality BMPs and other mitigation techniques associated with the Town Center/Newcut Road development and other similar developments in substantially similar watersheds where BMPs have been evaluated. BMPs will be evaluated within the overall development process to determine the ability of different BMPs to protect water quality."

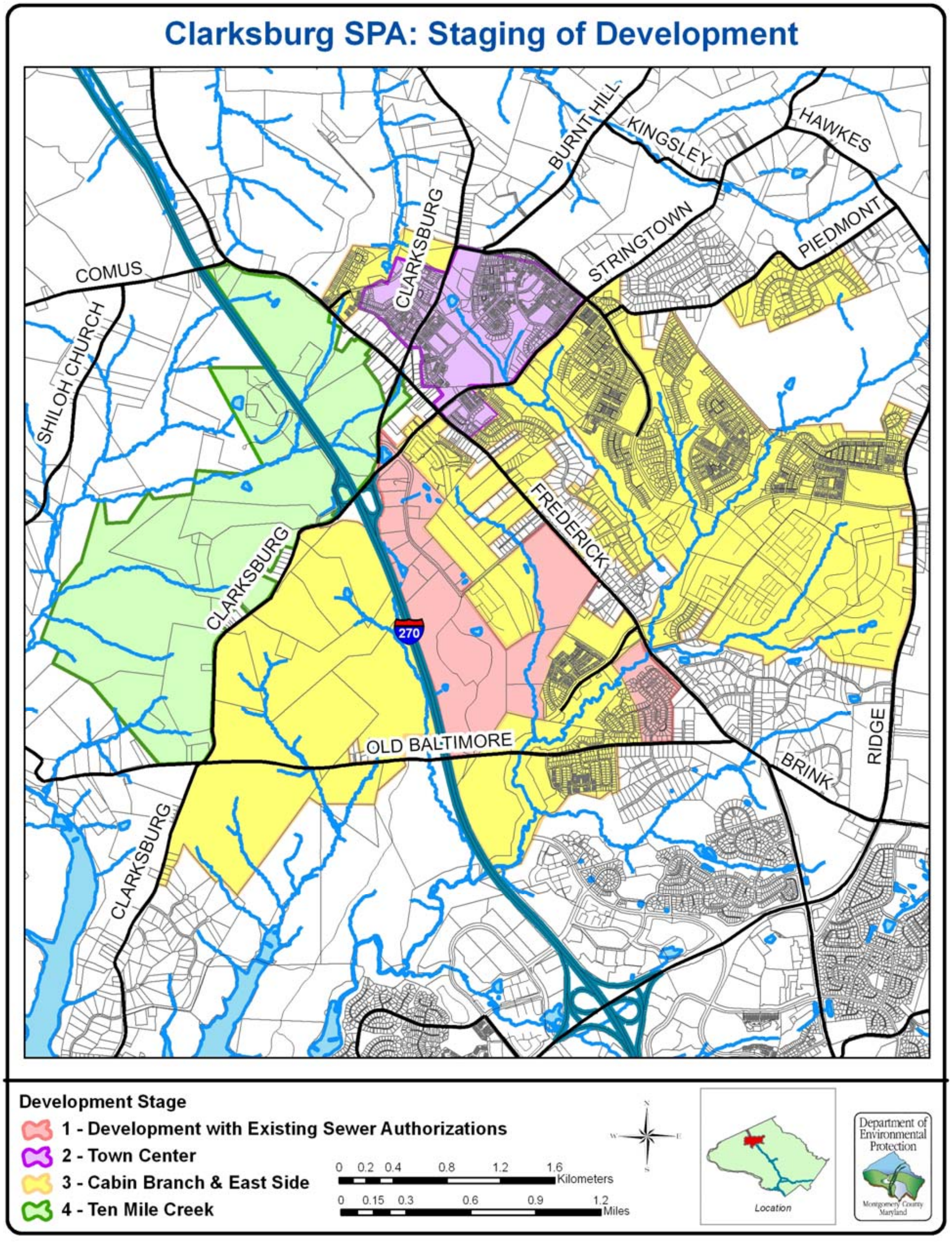


Figure 1.2. The Four Development Stages in the Clarksburg Master Plan Area.

DEP has been conducting baseline monitoring since 1994, satisfying the first trigger. The second trigger for Stage 4 "Community Building" was met during 2007. The third and final trigger, "The Eastside BMPs Monitored and Evaluated", is satisfied by this report.

Once all three triggers are met, the County Council will consider water and sewer category changes that will permit the extension of public facilities to Stage 4, the Ten Mile Creek watershed. Per the Master Plan (1994), as part of their deliberations, the Council "will evaluate the water quality results associated with Newcut Road and Town Center developments and other similar developments in substantially similar watersheds where BMPs have been monitored and evaluated" as part of their deliberations. In undertaking this evaluation, the Council shall "draw upon the standards established by federal, state, and county laws and regulations and determine if the methods, facilities and practices then being utilized by applicants as part of the water quality review process then in place are sufficient to protect Ten Mile Creek."

The Master Plan identified the Ten Mile Creek watershed as an *environmentally sensitive area* of county-wide significance. The Master Plan further described Ten Mile Creek in the following quotes:

- "…a fragile stream due to its delicate ecosystem, low *base flows*, and highly erodible stream banks"
- "…Ten Mile Creek exhibits characteristics that make it the most prone to environmental *degradation* from development."
- "…the most important watershed in the Planning area because it had the best or most extensive natural resources and the highest potential for undesirable development effects."
- "…the timing and sequence of development in Clarksburg respond to the unique environmental qualities of the area and help mitigate, in particular, development impacts to the environmentally sensitive stream valleys in the Ten Mile Creek watershed."

In this respect, Ten Mile Creek was different from other streams in the Master Plan study area and merited special consideration. The Master Plan recommended that development in the Ten Mile Creek watershed occur only after the implementation and evaluation of the initial water quality review process for Town Center/Newcut Road is completed.

According to the Master Plan, after conducting the assessments specified, the Council may:

1. Grant water and sewer category changes, without placing limiting conditions upon property owners.

2. Grant water and sewer category changes, subject to property owner commitments to take additional water quality measures, such as staging of development, to protect the environmentally fragile Ten Mile Creek Watershed.

3. Defer action on a Water and Sewer Plan category change, pending further study or consideration as deemed necessary and appropriate by the Council.

4. Consider other such land use actions as deemed necessary.

1.3 BMP Monitoring Status

When the Clarksburg Master Plan was written in 1994 it was anticipated that the 2,000th building permit would be issued in 25 to 30 years from the beginning of development. Instead, this staging trigger was met in 2007, roughly half the time anticipated. It was also expected that construction in the Newcut Road and Town Center areas would have been completed and that a sufficient time period would have elapsed for the effects of the development on water quality to be studied. However, fast-paced development, along with other issues such as the Clarksburg building moratorium and now the economic downturn, have resulted in large amounts of land disturbance without completion of development. Developers have not converted the majority of the S&EC BMPs to SWM BMPs even though large areas have been cleared, graded roads and utilities completed, final grades established for lots, and most of the lots built and occupied. Development in the Newcut Road and Town Center areas is ongoing and there has been insufficient time to study the effectiveness of structural SWM BMPs in protecting water quality. Similar delays have occurred in other SPAs. The shift in monitoring approach mentioned in Section 1.2.1, along with the development problems mentioned above has delayed post-construction monitoring results on the efficiency of SWM structures.

To determine whether a watershed has recovered from development stresses, development in the watershed should be complete. Although conclusions could be drawn on the efficiency of individual BMPs, the overall effect of development on the watershed can only be evaluated once construction in the watershed is completed. As long as construction is ongoing upstream of the monitoring sites, the potential construction effects could delay recovery of the stream.

Current data shows that the SPA design guidelines for S&EC allow streams to degrade during construction (Section 5). The existing SPA monitoring data is insufficient to make conclusions regarding the effectiveness of SWM BMPs and the ability of the stream to recover from the effects of construction. However, guidance on how to proceed with Stage 4 will be provided using the limited data available, technical literature, and best engineering judgment.

1.4 Clarksburg Monitoring Partnership

In addition to the BMP monitoring conducted by the developers, and the biological monitoring conducted by DEP, the Clarksburg Monitoring Partnership (CMP) is conducting separate but related research. The CMP is a consortium of local and federal agencies, and universities. It offers a collaborative approach to monitoring the long term aquatic ecosystem changes to the stream system resulting from the associated landscape transition from agricultural to medium and high density residential, commercial, and industrial land uses. Results of the CMP monitoring will supplement other SPA BMP monitoring and provide a comprehensive approach to document the effectiveness of land use planning and the implementation of modern S&EC and SWM BMPs.

The Clarksburg Monitoring Partnership includes:

- Montgomery County Department of Permitting Services
- Montgomery County Department of Environmental Protection
- Maryland-National Capital Park and Planning Commission
- University of Maryland, College Park campus
- USGS Water Resources Division, Baltimore, MD
- USGS, Environmental Resources Center, Reston, VA
- Virginia Polytechnic Institute and State University
- George Mason University
- United States Environmental Protection Agency (U.S. EPA) Landscape Ecology Branch, Research Triangle Park, NC
- U.S. EPA National Risk Management Research Laboratory, Cincinnati, OH
- U.S. EPA Office of Research and Development, Atlanta, GA
- U.S. EPA Environmental Science Center, Ft. Meade, MD

The opportunity to study the development process from the beginning to end will help document how the changes in topography and imperviousness will affect the *hydrology* and *geomorphology* of the receiving streams.

The CMP is using a *Before, After, Control, Impact (BACI) design* approach (Fig. 1.3) to assess the land use changes and the impacts to stream conditions. Three test areas were selected: two in the Newcut Road Neighborhood and one in the Cabin Branch Neighborhood (Fig. 1.3). An undeveloped control area was established in Little Bennett Regional Park and a final developed control area was set up in Germantown (Fig. 1.3). All the test areas have United States Geological Survey (USGS) flow gages installed and are collecting continuous stream flow data over time. Two rain gages monitor area rainfall and document local rainfall intensities to correlate rainfall intensity to stream flow characteristics. LiDAR (Section 4.1) imagery will assist in the mapping of landscape changes as a result of the landscape alterations in Clarksburg. Changes in hydrology and geomorphology will be linked to changes in the *benthic macroinvertebrate* and fish communities. Other private and public researchers are collecting information on changes to groundwater levels and quality. Changes to stream ecosystem structure and function are being done through advanced studies of community metabolism nutrient uptake and decomposition. This collaborative approach to monitoring long term change in an aquatic ecosystem has resulted in a comprehensive approach to document the effectiveness of land use planning and the use of modern S&EC and SWM BMPs.

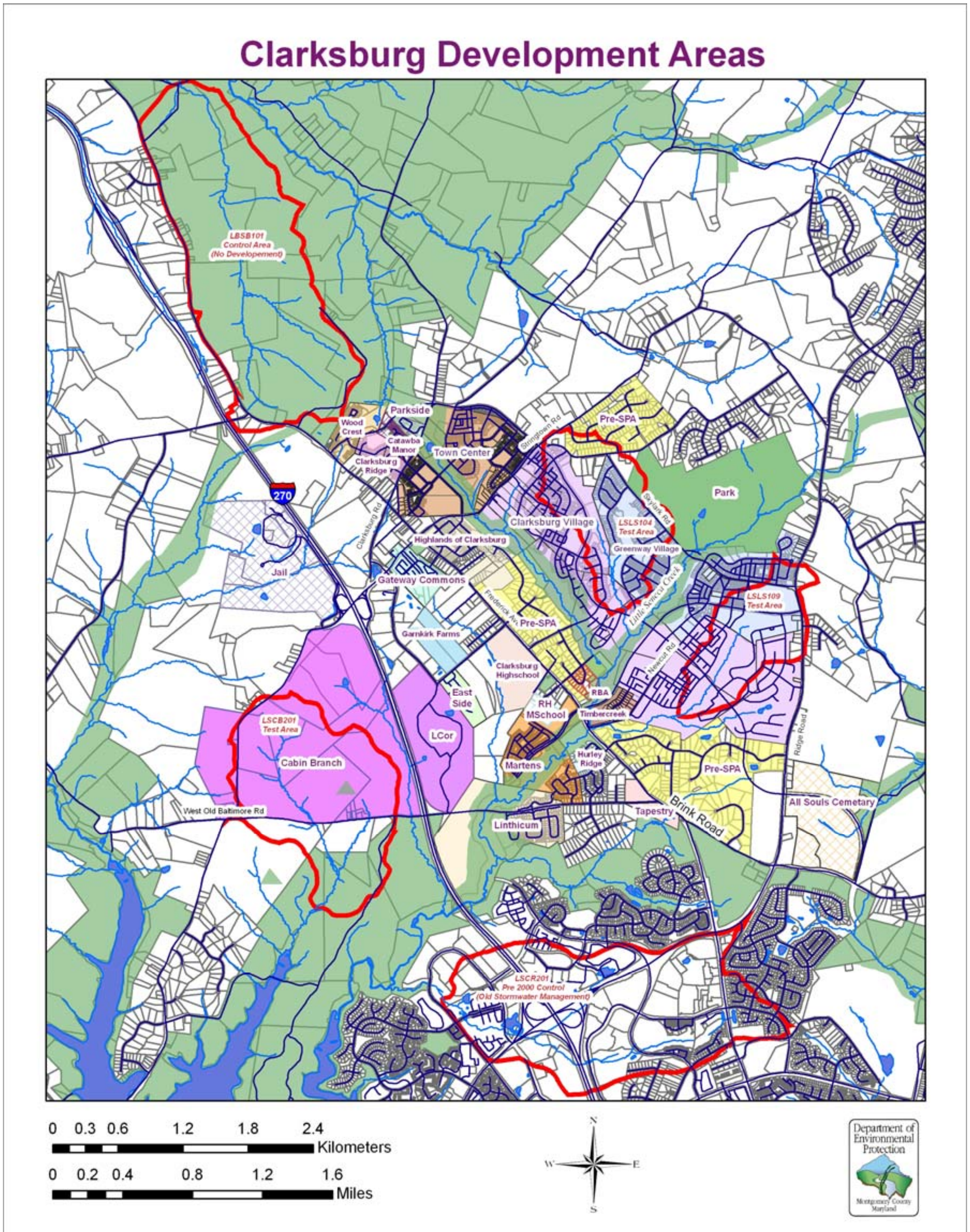


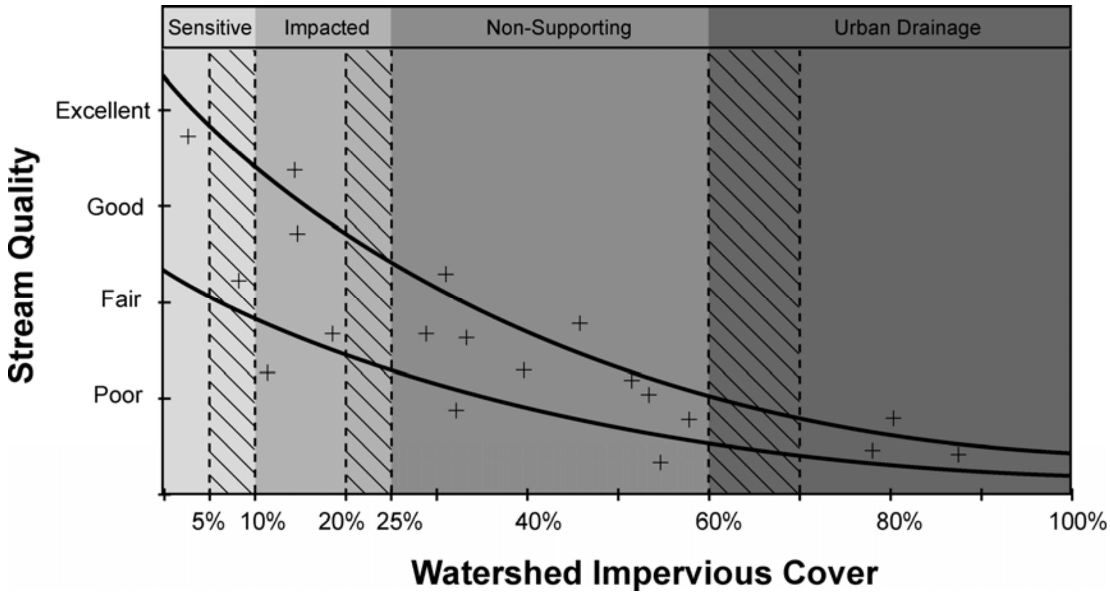
Figure 1.3. Location of the Clarksburg Monitoring Partnership BACI Three Test Areas and Two Controls Areas.

1.5 Streams and Imperviousness

There are a number of studies documenting the effects of imperviousness on stream water quality in Maryland (Klein 1979; May 1998; Boward et al.1999; M-NCPPC 2000; Fairfax Co 2001; Angermeier et al. 2004; Kazyak et al. 2005). All of these studies found that impervious cover between 5% and 15% produce significant declines in water quality. The strong relationship between increasing imperviousness levels and declining stream health is also supported in regional and national studies, such as Arnold and Gibbons (1996). There are also indications that highly compacted soils like those typically found on residential lawns and sports fields act similarly to impervious area preventing *infiltration* of precipitation into the ground.

Increasing impervious surface in a watershed affects streams by intercepting rainwater and eliminating the natural functions of the soil. In an undisturbed environment, most rainwater percolates through soil prior to discharging into a stream. The functions of soil and infiltration include: 1) filtering contaminants such as pesticides, road salt, nutrients from fertilizer, and *hydrocarbons* found in oil and grease, 2) cooling water temperature, and 3) slowing the rate of discharge into the stream. Increased levels of impervious surface reduces these functions, and streams typically experience increased temperatures during storms, increased contaminants and sediments in surface water, and wider flow fluctuations during floods and droughts. These changes cause streams to degrade.

One of the most widely used predictors of the effects of imperviousness on water quality in streams is the Impervious Cover Model (ICM) (Fig. 1.4) created by the Center for Watershed Protection (CWP 2003) and updated by the Chesapeake Stormwater Network (CSN 2008). The ICM defines four categories of urban streams based on how much impervious cover exists in their subwatershed: *high quality streams*, *impacted streams, non-supporting streams,* and *urban drainage*. The ICM can be used to develop specific quantitative or narrative predictions for stream indicators within each stream category. These predictions define the severity of stream impacts with respect to changes in stream hydrology, alteration of the stream corridor, stream habitat degradation, declining water quality and loss of aquatic diversity.



(CSN 2008)

Figure 1.4. The Reformulated Impervious Cover Model

The general predictions of the ICM are as follows:

- Stream segments with less than 10% impervious cover (IC) in their contributing drainage area continue to function as high quality streams, and are generally able to retain their hydrologic function and support *good* to *excellent* aquatic diversity.

- Stream segments that have 10 to 25% IC in their contributing drainage area behave as impacted streams and show clear signs of declining stream health. Most indicators of stream health will fall in the *fair* range, although some segments may range from *fair* to *good* as *riparian* cover improves. The decline in stream quality is greatest towards the higher end of the IC range.

- Stream segments that range between 25 and 60% subwatershed impervious cover are classified as non-supporting streams (i.e., no longer supporting their designated uses in terms of hydrology, channel stability habitat, water quality, or biological diversity). These stream segments become so degraded that any future stream restoration or riparian cover improvements are insufficient to fully recover stream function and diversity (i.e., the streams are so dominated by subwatershed IC that they cannot attain pre-development conditions).

The impervious cover of the Newcut Road and Town Center areas is over 25%, classifying those subwatersheds as non-supporting streams according to the ICM. The impervious cover for the Whelan Lane I-3 area in the Stage 4 Ten Mile Creek watershed has a 15% imperviousness cap for each of the two properties. The impervious cover of the MXPD zoned land in the Stage 4 Ten Mile Creek headwaters east of I-270 and west of Frederick Road would be over 25% and classified as non-supporting. The remaining developable land in the Stage 4 Ten Mile Creek area is zoned RE-1/TDR-2 with an estimated 20% to 25% imperviousness cover. This area would be described as impacted/non-supporting according to the ICM.

The ICM has been extensively tested in ecoregions around the United States and elsewhere, with more than 200 different studies confirming the basic model for single stream indicators or groups of stream indicators (CWP 2003).

Two recent academic research studies have specifically explored the impervious cover stream quality relationship in *headwater streams* located in Montgomery County. The first, by Goetz et al. (2003), looked at stream quality and detailed subwatershed land cover data for 245 streams in Montgomery County and concluded:

> "We found a stream health rating of *excellent* required no more than 6% impervious cover in the watershed and at least 65% tree cover in the *riparian zone*. A rating of good required less than 10% impervious cover and 60% tree cover in the riparian zone."

The authors also present data that indicate a shift to *poor* stream health occurring when watershed impervious cover exceeded 20% in Montgomery County streams.

The second study by Moore and Palmer (2005), investigated 29 urban and agricultural headwater streams in Montgomery County. They found: "*Taxa* richness was related negatively and linearly with the amount of impervious cover" with a pronounced shift to poor richness values at around 20 to 25% subwatershed impervious cover. Considered together, these research studies strongly reinforce the validity of the ICM as it pertains to rural and urbanizing streams within Montgomery County.

The 2003 (MCDEP) update to the Countywide Stream Protection Strategy (CSPS) observed that impervious and highly compacted surfaces covering the landscape affect how much water infiltrates and how much runs off. A regression model developed by DEP, and based solely on available county stream quality and watershed impervious area data, predicts that aquatic insect IBIs (Section 5) decline to the *fair* category when imperviousness exceeds 8%. When imperviousness exceeds 21%, the model predicts that aquatic insect IBIs shift to the *poor* category (Fig. 1.5).

Additional research, such as that being conducted in the SPAs, is needed to assess the extent to which the combined effect of modern stormwater controls, stream buffers, and forest reforestation, can help mitigate the effects of increasing imperviousness and compacted soil conditions in urban and suburban watersheds. The Center for Watershed Protection Study (CWP 2003) further notes that it is premature to presume that SWM controls are of limited value in maintaining biological diversity in small streams. Most SWM control structures studied to date were designed using now obsolete design standards to control certain types of storms, and were not specifically designed to protect stream habitat or to optimize prevention of downstream channel erosion. Forest retention and buffers may also provide benefits that have not been well quantified (CWP 2003).

Few studies have actually followed a small watershed from pre-construction through to the build-out of projects to evaluate the ability of various combinations of SWM controls, along with stream buffers, forest conservation, and other stormwater pollutant controls in mitigating watershed development impacts. As the S&EC BMPs are converted to SWM BMPs in the Clarksburg Special Protection Area, DEP will be able to better quantify how redundant and modern best management practices can help mitigate the effects of imperviousness on the biological communities in our streams. The data to date suggests that although SWM controls and other management techniques like forest buffer can mitigate some impacts to water quality, these techniques cannot prevent stream degradation from increased imperviousness.

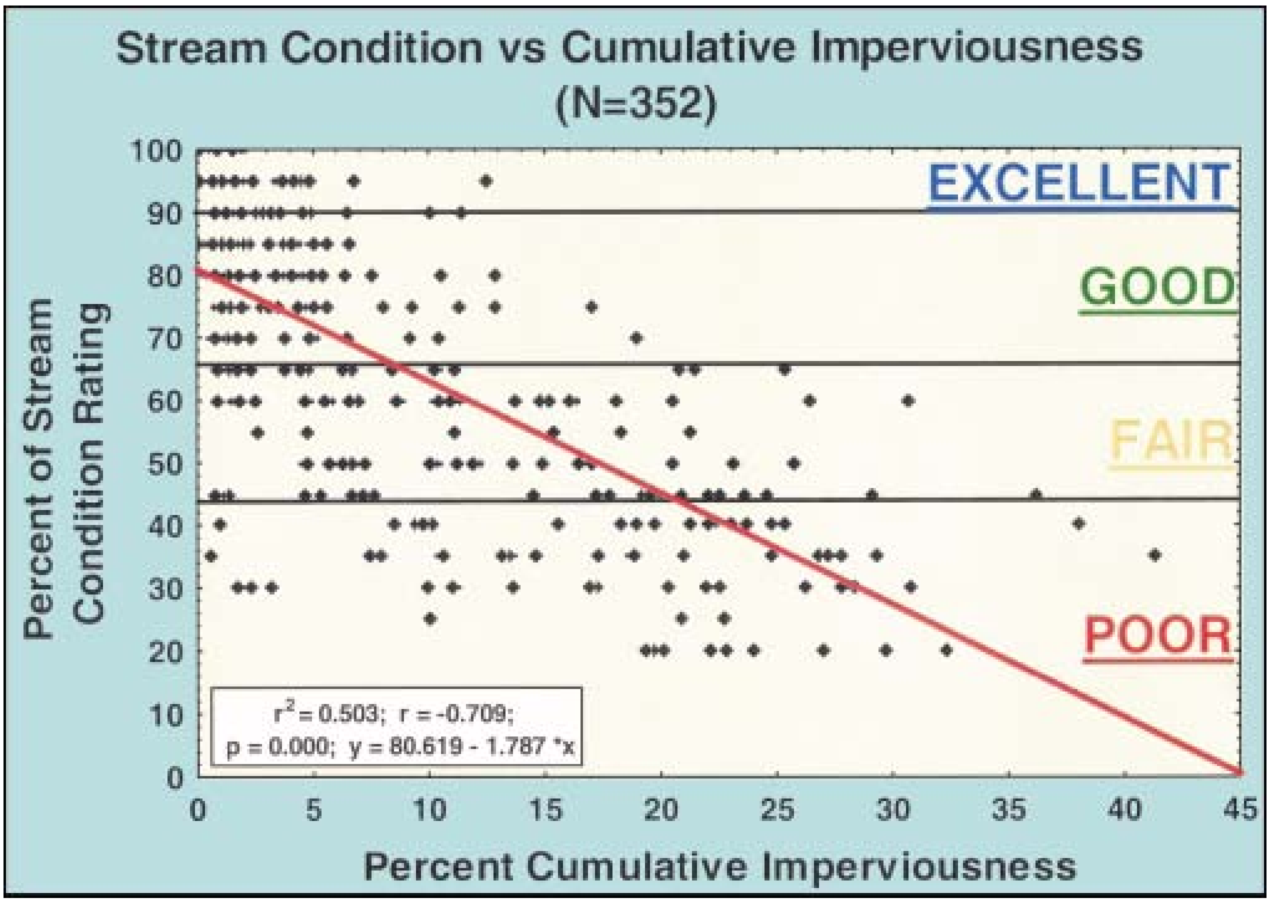


Figure 1.5. Preliminary Relationship Between Imperviousness and Stream Condition Ratings in Montgomery County, MD (MCDEP 2003).

1.6 Development and Imperviousness

There are continuing conflicts between SPA goals for environmentally sensitive developments and other development requirements that sometimes foster increased impervious areas including: Master Plan-designated *transferable development right (TDR)* receiving areas, zoning density, construction sequence, and road grade requirements that require extensive *cut and fill*. These increased development pressures compete with the protection of natural stream systems.

Using an impervious area limit is one of the methods used to minimize the effects of development on natural resources. The Piney Branch SPA and the Clarksburg SPA were created with very limited or no imperviousness cap for new development (in the Clarksburg Master Plan, there is a 15% impervious limit recommended for specific sites on the west side of I-270). As the importance of minimizing imperviousness levels in order to maintain healthy stream conditions became better understood, Upper Paint Branch was designated as an SPA by County Council resolution in 1995 with an accompanying *Environmental Overlay Zone*, adopted in July 1997, that included a 10% impervious cap on new development, as well as restrictions on specific land uses that typically have significant adverse environmental impacts on sensitive natural resources. This Overlay Zone was amended in 2007 to revise the imperviousness limit for new development downwards to 8%.

The Upper Rock Creek SPA was designated as an SPA by the County Council with the approval of the Upper Rock Creek Master Plan by resolution on February 24, 2004. The Environmental Overlay Zone for this SPA was adopted on October 26, 2004, and it designates an 8% imperviousness limit only on private development or subdivisions that are served by community sewer.

1.7 Landscape Changes and Streams

In addition to imperviousness, stream water quality can also be affected by landscape changes. The clearing of vegetation and the surface grading and compaction of native soils for site preparation, road and utility installation alters the original topography and hydrology. The rolling topography like Clarksburg must be flattened to meet maximum slope requirements for roads and the tops of hills are cut and valleys are filled in to create a landscape suitable for development. This process creates major changes to the surface (topography) and, as a result, the surface and subsurface water patterns are permanently altered.

Stream buffers are used to minimize impacts to hydrology; however, the development process allows for cutting and filling up to the limits of disturbance along the stream buffer. This can result in altered hydrology and impacts to local springs and seeps.

1.8 Environmental Site Design

Recently, the Maryland Department of Environment (MDE) proposed regulations to implement the Stormwater Management Act of 2007. These regulations would require the use of *Environmental Site Design (ESD)* practices wherever possible to control runoff and pollution from both new development and redevelopment. ESD would require integrating site design, natural hydrology, and smaller controls to capture and treat runoff to better maintain natural drainage pathways and minimize development impacts to receiving streams.

2. SPA Water Quality Review Plan and BMP Monitoring Review Process

Before a development in an SPA is built, there is an extensive plan review and approval process to assure that all SPA requirements are met. This section details the plan review process used to approve the design and layout of BMPs in an SPA. The section will also provide details as to how the monitoring requirements for an SPA development are arrived at.

DPS sets site-specific performance goals prior to the initial meeting with the developer (the pre-application meeting). Performance goals aim to:

1. Protect stream/aquatic life habitat;
2. Maintain stream base flow;
3. Protect seeps, springs, and wetlands;
4. Maintain natural on-site stream channels;
5. Minimize storm flow runoff increases;
6. Identify and protect stream banks prone to erosion and slumping;
7. Minimize increases to ambient water temperature;
8. Minimize sediment loading;
9. Minimize nutrient loading; and
10. Control insecticides, pesticides, and toxic substances.

2.1 Water Quality Plan Review Process

Prior to submission of the *water quality inventory* and formal plans for review and approval, an applicant for development must attend a pre-application meeting with the DEP, DPS and the M-NCPPC. There are several purposes of the meeting. These include:

- Presentation of the proposed performance goals that are to be used for the development of the site layout;
- Discussion of the conceptual approach and possible locations of preferred structural and non-structural best management practices and their estimated suitability for achieving the performance goals; and
- Development of innovative site layouts and linked best management practice options to maximize protection of water quality, stream habitat, and aquatic life.

Preliminary and Final Water Quality Plans are then developed and submitted to the respective lead agencies for their review and approval. Elements of these plans include SWM concept plans, S&EC concept plans, BMP monitoring plans, and description of other mitigation practices including minimization of road widths and use of open section roads. Public notice of the submission of the Preliminary Water Quality Plan is made by DPS so that an informational hearing can be held if requested. The Planning Board gives final approval to a water quality plan after DPS approves the plan components required under their review. Some plans can be submitted as a combined preliminary/final water quality plan. With the exception of the Upper Paint Branch SPA, only a water quality inventory instead of a full water quality plan is necessary if:

1) A project on agricultural, residential, or mixed use zoned property contains a proposed impervious area of less than 8% or a cumulative area of 10 or fewer acres and a proposed impervious area of less than 15% of the total land area;

2) A project on property zoned for industrial or commercial use consists of a cumulative land area of two or fewer acres covered by the development approval application

Performance goals established for each development project as part of the Water Quality Plan should protect natural features. However, because the S&EC and SWM structures were sited after building locations and other infrastructure, some approved land development projects with SPAs have not protected the natural features necessary to sustain important aquatic resources. If S&EC and SWM structures are not considered in the early stages of preparing a development plan, opportunities for sustainability are not fully achieved and resources may not be fully protected. By not siting SWM early in the planning process the S&EC and SWM structures are typically pushed to the perimeter of the site. In some cases, this has resulted in locating S&EC structures and SWM structures in areas with high water tables, thereby diminishing their performance.

2.2 BMP Monitoring Review Process

The goal of the BMP monitoring program is to assess the effectiveness of SPA S&EC structures and SWM structures in maintaining water quality.

A monitoring plan is designed to evaluate the effectiveness of BMPs and innovative site design and achievement of site performance goals. SPA BMP monitoring often includes monitoring of: groundwater elevations, groundwater chemistry, instream temperature, instream (surface water) chemistry, stream baseflow and storm flow, stream geomorphology, *total suspended solids (TSS),* and pollutant loading reductions. Monitoring follows the procedures outlined in the Montgomery County Department of Environmental Protection Best Management Practice Monitoring Protocols (MCDEP 1998).

The information collected, when combined with data from the County's biological stream monitoring program, is used to evaluate the effectiveness of the County's current BMP designs over a range of drainage areas, land use, and impervious levels in protecting water quality. Recognizing practical site conditions, feasibility, and cost considerations, BMP monitoring is not required for all SPA development projects. There are many projects where, because of the relatively small property sizes or other reasons, no BMP monitoring is required.

Results of this data will be used by DPS to evaluate BMP effectiveness and then to target the most effective BMPs to new development activities in the other SPAs and elsewhere throughout the County. DEP will continue to annually monitor and report trends in stream conditions in all SPAs.

2.3 SPA BMP Technology

The requirements for design of S&EC and SWM structures in SPAs exceed the minimum requirements set forth by the Maryland Department of the Environment. Redundancy and over-sizing of structures is one of the primary measures used to improve performance.

2.3.1 Sediment and Erosion Control (During Construction)

Sediment and Erosion Control Plans in SPAs are required to provide redundant treatment. In early reviews of Water Quality Plans for land development projects, DPS required the use of upland sediment basins/traps with an *outfall* to basins/traps further down grade or by providing basins with forebays. This approach was determined to be ineffective because the upland basin would typically discharge to disturbed areas or would be disturbed during construction. Recognizing these design considerations, the design standards were revised. The current standard design requirement for S&EC in SPAs is to provide oversized basins with forebays near the outfall of the property, emphasize limiting disturbance and promoting immediate stabilization of disturbed areas.

In addition, in an attempt to improve the efficiency of S&EC in SPAs, Montgomery County has adopted a number of features for S&EC in SPAs that are more stringent than MDE and County S&EC requirements for construction sites outside of SPAs. The adopted features include the following:

- perforated risers with gravel or filter fiber jackets,
- filter fence baffles,
- floating skimmers,
- dual basins in series,
- greater storage volumes, and
- utilizing combinations in the form of a treatment train to improve performance.

2.3.2 Stormwater Management (Post Construction)

The Maryland Department of Environment (MDE) 2000 Maryland Stormwater Design Manual provides a unified stormwater sizing criteria that specifies how stormwater structures are designed. The three minimum components necessary to meet state stormwater management requirements are:

- *water quality volume (WQv)*;
- *channel protection storage volume (Cpv)*; and
- *recharge volume (Rev)*.

The water quality volume is approximately the first inch of rain over the impervious area. It treats the "*first flush*" of contaminants coming off of impervious surfaces. In SPAs, redundant controls, also known as treatment trains, are required for stormwater quality control. However, the allowable drainage area to any one filtering structure has decreased drastically since the SPA program started. Originally there were only guidelines and no set limits for drainage areas to a filtering structure. The drainage area limit has decreased over the years to its current limit of three acres to a surface sand filter and one acre for all other water quality structures (including biofilters, infiltration trenches, and proprietary structures). This was done to increase the efficiency of the structures and to limit the area that is not treated (or is minimally treated) as the filtering structures become clogged and require maintenance. Additionally, runoff from areas intended for vehicular use must be pretreated prior to entering the water quality structure. This is typically done using a vegetated filter strip or a *hydrodynamic structure* (concrete separator).

The channel protection storage volume (also called the water quantity volume) is the volume necessary to hold the *one year 24 hour storm,* approximately 2.6 inches rainfall. Storage and slow release of the channel protection volume is intended to protect streams from erosion due to high velocity water scouring the banks. In the SPAs, the requirement for control of the one year storm event was in place prior to the adoption of the 2000 MDE manual.

The recharge volume is intended to maintain the ground water table and natural hydrology. Groundwater recharge has also been a requirement for developments in the SPAs from the beginning of the program. The adoption of the 2000 MDE Stormwater Design Manual provided additional methods to consider for providing groundwater recharge as well as the minimum recharge volume that must be provided.

Many of the elements set forth by MDE in the 2000 Stormwater Design Manual are a reflection of the design requirements that Montgomery County has been imposing on developments in SPAs. The requirements in the SPAs still exceed the requirements of MDE.

3. BMP Effectiveness

BMPs are evaluated based on efficiency, performance, and effectiveness. BMP efficiency compares the amount of pollution entering the BMP to the amount of pollution leaving the BMP. BMP performance evaluates how well the BMP is removing pollutants compared to literature values. BMP effectiveness is the BMP's ability to meet one or more of the SPA Program performance goals listed in Section 2.2. SPA performance goals are desired outcomes set at the beginning of the SPA development process as part of the Water Quality Review Process. Developers are responsible for funding the monitoring within their property's limits to document achievements of the site performance goals.

Early monitoring for the SPA program evaluated BMP effectiveness by measuring water quality at the stormwater outfall (where the stormwater for the site discharges into the receiving stream) or upstream and down stream of the outfall (Figure 3.1). The results of that monitoring are provided in Section 3.1. Later monitoring focused on specific structural BMP pollutant removal efficiency, measuring the amount of pollutant entering a BMP versus the amount of pollutant exiting a BMP (Figure 3.1). BMP pollutant removal efficiency monitoring results are found in Sections 3.2 and 3.3.

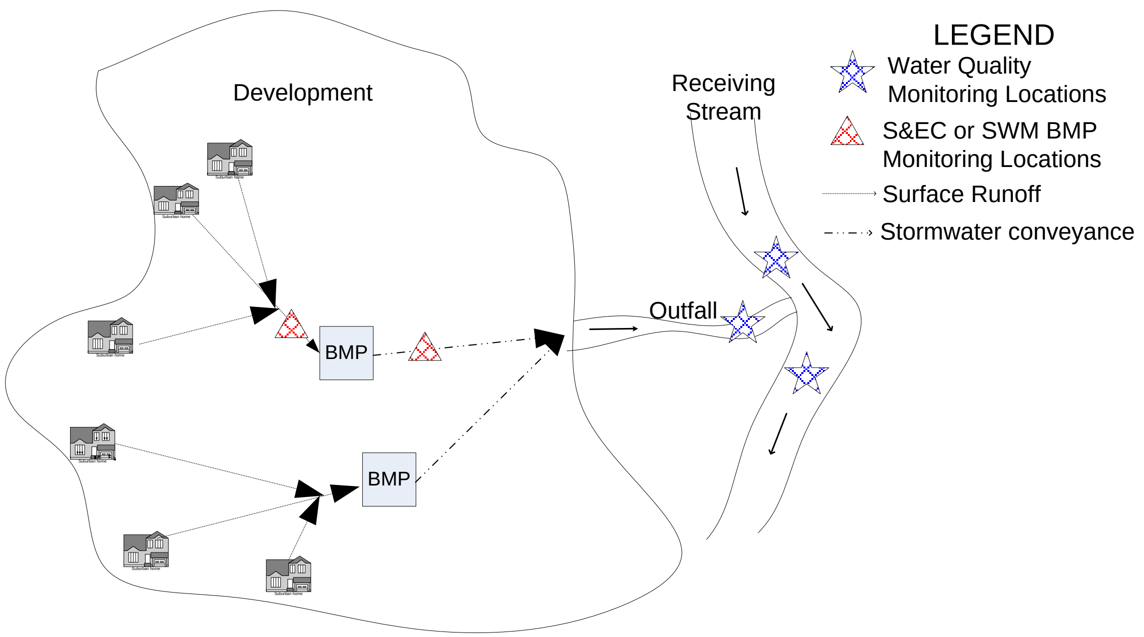


Figure 3.1. Monitoring Locations.

Maps of the SPA developments and a list of projects with the parameters monitored are located in the Technical Appendix. Figure 3.2 provides a breakdown of the status of the BMP monitoring projects being conducted as part of the SPA program in 2007. Fourteen projects have completed monitoring. Ten projects were collecting post-construction data, four of which were monitoring BMP pollutant removal efficiency using automated sampling. The majority of projects remain in the construction phase. Fourteen projects are collecting data on construction conditions. Eleven of these projects are required to perform structural S&EC BMP efficiency monitoring. Five projects were conducting pre-construction (baseline) monitoring.

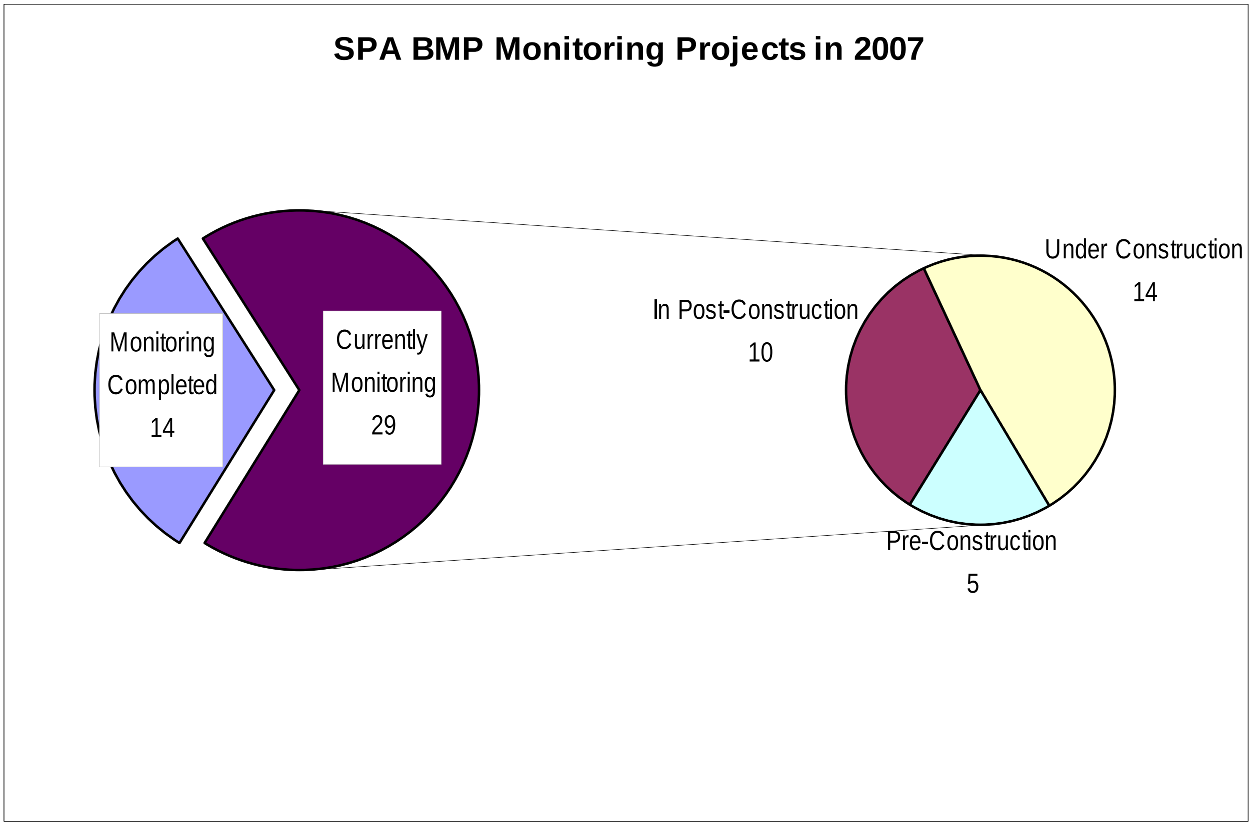


Figure 3.2. SPA BMP Monitoring Project Status in 2007.

3.1 Water Quality Monitoring

Fourteen SPA projects fulfilled monitoring requirements before the 2007 monitoring year. These completed projects submitted data on water quality parameters such as stream and hydrological conditions to document the achievement of site performance goals. Names of projects and years monitored are provided in the Technical Appendix.

<u>3.1.1 Stream Temperature</u>

Eight projects were required to monitor stream temperatures. The majority (seven properties) identified no thermal impacts, indicating that the goal of minimizing temperature impact was achieved. It is possible that dilution effects may have buffered thermal impacts, as some properties release stormwater to larger, second order streams.

The results from the other property were inconclusive due to inconsistencies with data collection, a lack of calibration records, and consultant coordination.

3.1.2 Embeddedness

Six of the fourteen completed projects were required to submit data on embeddedness, which measures the extent to which sediment has covered the stream bottom and filled in spaces between the rocks, cobble, and gravel. Results from four of these projects indicate there were no impacts. One project, Briarcliff Manor West, in the Upper Paint Branch SPA, had the highest embeddedness scores during construction at a station below the sediment pond outfall, although scores were not drastically different from baseline. Embeddedness levels declined during post-construction. The Shady Grove Road project, in the Piney Branch SPA, also had embeddedness impacts during construction, but post-development monitoring data indicated embeddedness was reduced to pre-construction levels. Embeddedness can be subjective and difficult to assure consistency.

3.1.3 Groundwater Levels

Groundwater monitoring was conducted at six of the completed projects. Monitoring requirements were modified for two of these projects and only five projects have data available for analysis. Three projects showed no impacts to groundwater, one project was deemed inconclusive, and one property experienced groundwater impacts. Before and during development, the data from the Briarcliff Manor West property matched very well with a USGS well that has been used as a control (Figs. 3.3 and 3.4). Following development, groundwater levels at Briarcliff Manor West were reduced in relation to the USGS well. This indicates that groundwater recharge has been affected by development of the site.

3.1.4 Groundwater Chemistry

Groundwater chemistry was monitored at two of the completed projects, both of which produced inconclusive results. The name of the projects and the compounds monitored are located in the Technical Appendix. BMP monitoring of groundwater chemistry before and after construction at one well at the Clarksburg Detention Center (Clarksburg SPA) revealed nitrate levels above the EPA Drinking Standard of 10 mg/L. Levels ranged from 15.0 to 31.2 mg/L. During the late 1970’s, a parcel of land near the well was used as a site for disposal of sewage sludge, which may explain the elevated levels.

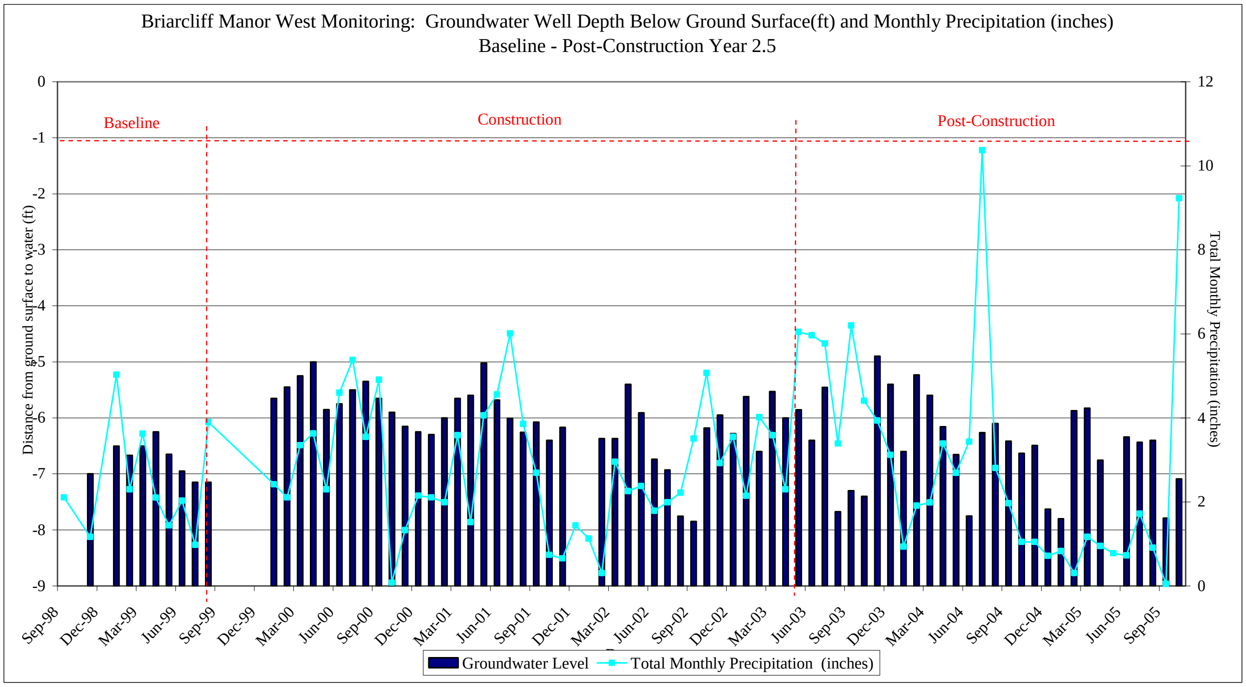


Figure 3.3. Briarcliff Manor West (Upper Paint Branch SPA) Groundwater Monitoring.

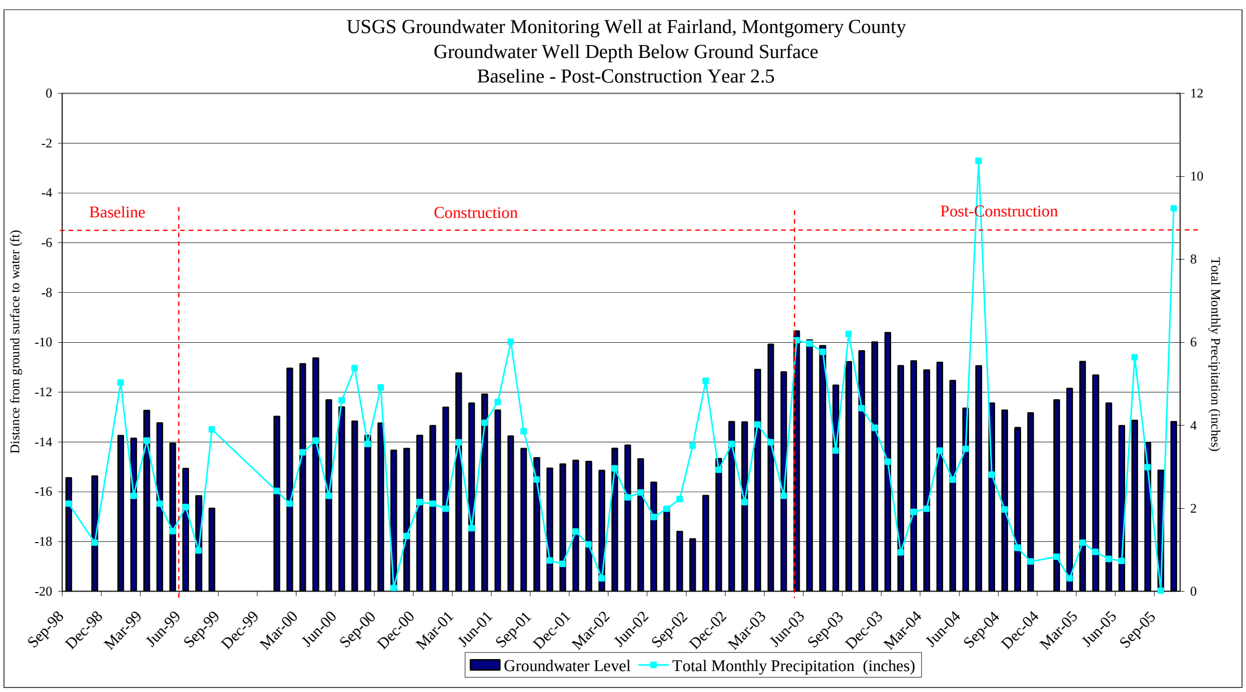


Figure 3.4. USGS (Fairland in Upper Paint Branch SPA) Groundwater Monitoring.

3.1.5 Instream Chemistry

Instream chemistry monitoring was required at one of the completed projects through all phases of development. The dates of monitoring and a list of the compounds monitored are located in the Technical Appendix. *Grab samples* were collected in a tributary of Piney Branch, Sheep's Run, directly below the area where the Peter's Property SWM outfall discharges. Monitoring revealed an increase in TSS concentrations during construction, which decreased after site stabilization and subsequently returned to pre-construction levels during the post-construction period. Monitoring results also suggested that *total kjeldahl nitrogen (TKN)* levels may have been slightly elevated during the conversion process of S&EC to SWM.

3.1.6 Continuous Stream Flow

Continuous stream flow was required at four of the completed projects. Unfortunately, stream flow sampling proved extremely challenging and very little useable data was produced from this monitoring. Issues with how equipment was installed and maintained, general equipment failure, and errors and inconsistencies with how data was reported, managed, and stored impeded interpretation of the data. Additionally, monitoring of stream flow was terminated at two projects: one was ended due to equipment failure and lack of data, and the other because the staff gage plate was catching debris and redirecting flow, causing stream erosion. Current SPA surface gages are operated by Montgomery County, U.S. EPA, and the USGS through several joint funding agreements to improve data collection and availability.

3.2 Sediment and Erosion Control (S&EC) BMP Monitoring

The S&EC BMP performance is evaluated during construction by measuring the removal efficiency of total suspended solids (TSS). The removal efficiency is monitored using grab sampling or automated samples to collect storm flow entering and leaving a S&EC structure.

3.2.1 Grab Samples

A manual grab sample is collected by inserting a container into the flow at the inlet(s) and outfall of a structure. Data collected via the grab sample method can be used to represent pollutant removal efficiency as the difference (expressed as a percentage) between the concentrations of pollutants entering the structure versus the concentration of pollutants leaving the structure but is not representative of the entire storm event. Concentrations of suspended sediment and chemical parameters can vary throughout a storm event, with grab sampling only offering a snapshot of the concentration at a discrete point in time.

A total of 101 grab samples have been collected from 2002 to 2007 from SPA S&EC structures (Technical Appendix). In some cases, grab samples were required as part of the original monitoring plan; in other cases, when it was determined that a structure could not be sampled using automated equipment, monitoring requirements were adjusted during S&EC so grab samples were collected instead. The practice of substituting grab samples for composite samples is no longer acceptable.

As indicated in Figure 3.5, monitoring results from grab samples continue to show S&EC structures receiving dirty, sediment-laden water (likely to occur during the early development periods involving cutting, filling and grading) are generally effective. Results depicted in Figure 3.6 show a general decrease in sediment concentrations leaving S&EC basins and traps, with a median removal efficiency of 77.7% when the inlet concentrations are greater than or equal to 100 mg/L.

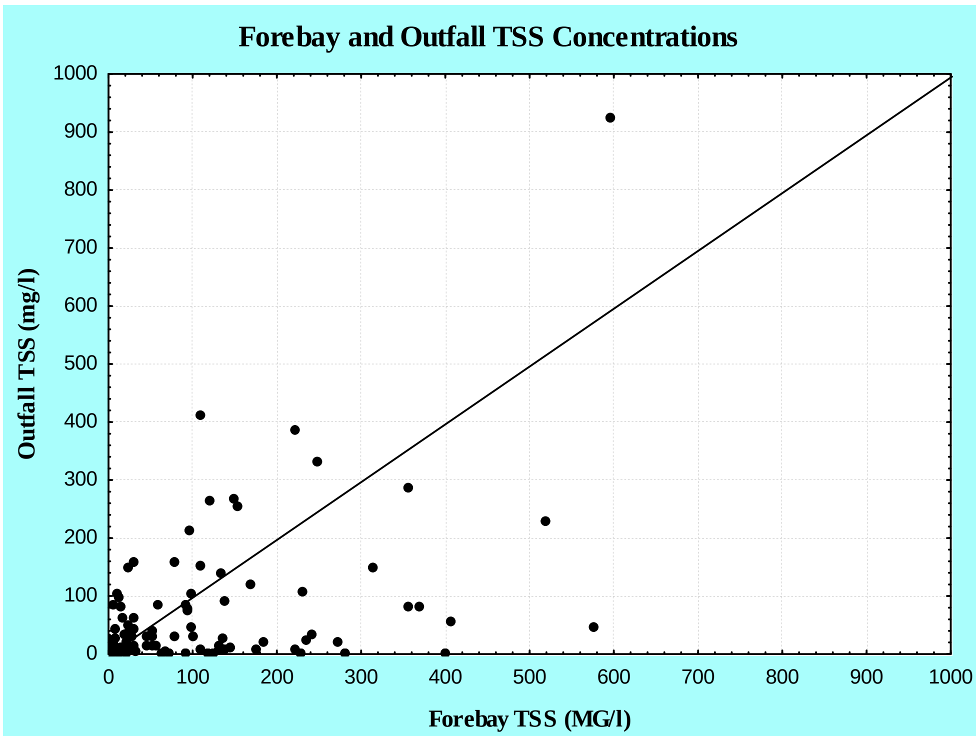


Figure 3.5. Forebay (Inlet) and Outfall TSS Concentrations (grab sample data).

At concentrations below 100 mg/L, the results are much more variable with a median removal efficiency of only 21.7% (Fig. 3.7). In some cases, dirtier water was leaving the BMP than was entering. The less polluted water (less than 100mg/L) entering the S&EC structures could be the result of the sampling event taking place fairly late in the grading and site preparation process during the period where most of the cut and filling was completed and final lot and road grades were completed. Soils are compacted during this phase to maintain the surveyed final grades. The higher outfall concentrations could be from the resuspension of fine clays and silts already in the control structure basin. As projects get closer to completion and less exposed earth is present on a site, there may be more sediment accumulated from prior storms getting washed out of structures than is being trapped. In response to this finding, the County is implementing procedures so that S&EC structures are converted to stormwater structures once the drainage area to the individual treatment train is complete, resulting in earlier conversion to SWM structures and less sediment discharging into the streams.

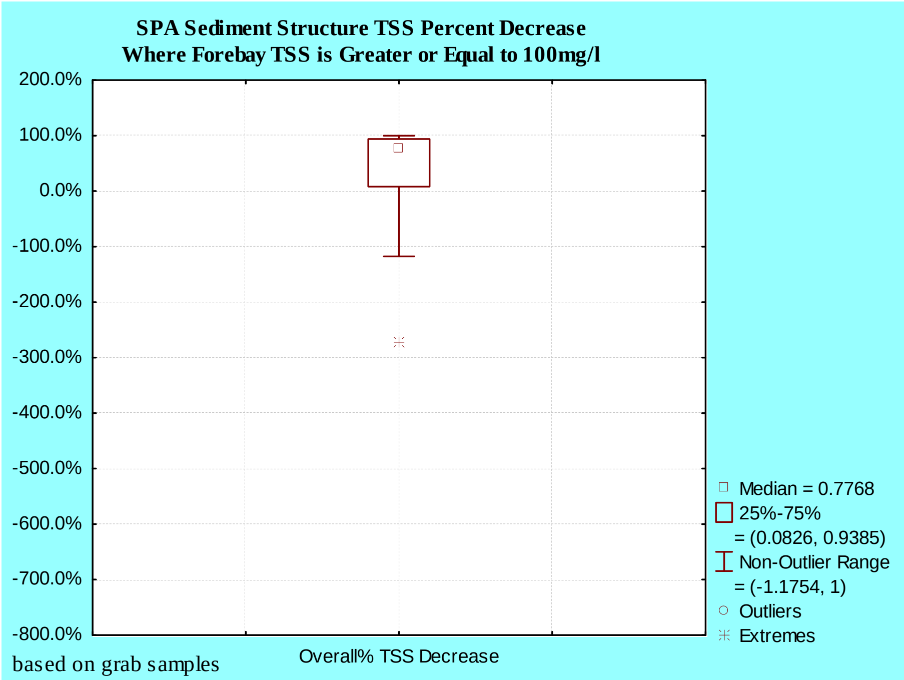


Figure 3.6. Percent Difference in Forebay and Outfall TSS Concentrations Where Forebay TSS Values are Greater or Equal to 100 mg/L (grab sample data).

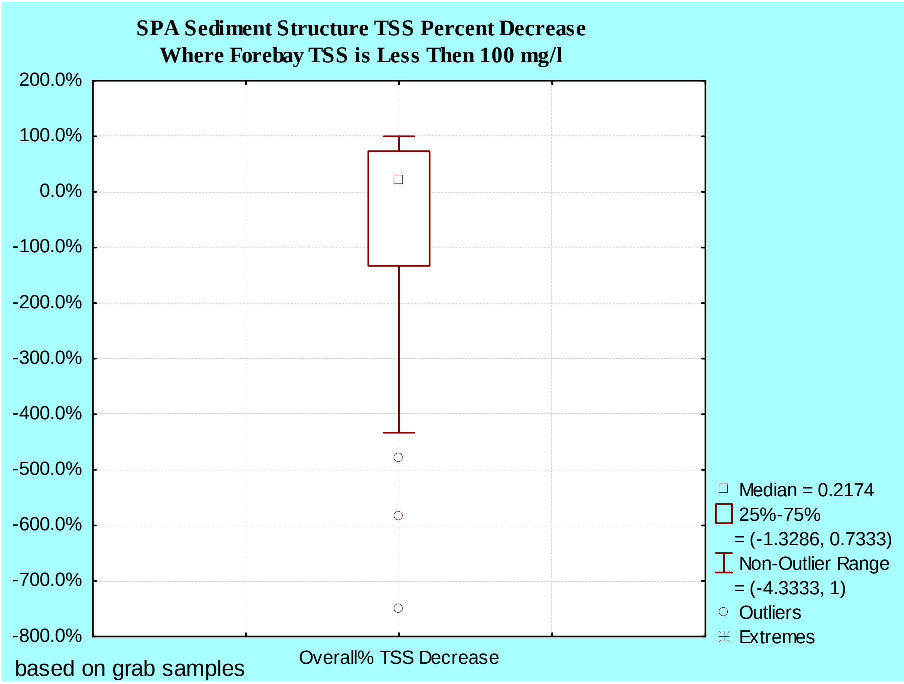


Figure 3.7. Percent Difference in Forebay and Outlet TSS Concentrations Where Forebay TSS Values are Less Than 100 mg/L (grab sample data).

3.2.2 Flow-weighted Composite TSS Sampling

Automated samplers are used to collect stormwater samples at intervals based on the estimated duration of the storm event. Following the event, samples are manually composited based on the flow to characterize the quality of stormwater discharge. Storm load efficiencies are then calculated and BMP percent removal efficiency is used to compare the mass of pollutant entering the S&EC or SWM BMP structure versus the mass of pollutant leaving the structure.

Flow-weighted composite BMP sampling can be reported using several different methods (Strecker et al. 1999). Individual storm load efficiency was the method selected to analyze the SPA monitoring results. Load efficiency of a structure is considered more accurate than examining efficiency independent of water volume, as is the case for grab samples. Due to the limitations of grab sampling, data collected from the two methods cannot be directly compared.

Although a better measure of BMP efficiency, DEP and the consultants who perform the flow-weighted composite sampling for S&EC have found it extremely challenging to obtain good data for a number of reasons including:

- Equipment problems,
- Structure configurations that do not allow for accurate sampling,
- Unaccounted for groundwater inputs, and
- Weather-related difficulties (i.e. insufficient rain amounts, storm events outside of normal business hours).

The configuration of a structure can change frequently as construction progresses, and occasionally some inlets stop receiving flow or other inlets may be added between sampling events. Additionally, some of the structures monitored were found to have intersected groundwater during installation. This resulted in continuous flow leaving the structure, making it difficult to define a storm flow event. Backwater at the inlets can make it impossible to capture a positive or accurate flow needed to calculate a pollutant load. Low flow entering or leaving the structure, as well as equipment anomalies and malfunctions, have also prevented the collection of flow-weighted data.

A limited amount of flow-weighted storm sampling data is available for S&EC. Some projects have not been able to produce meaningful data due to sampling difficulties and consultant error. Flow-weighted composite samples were consistently obtained for three projects: Clarksburg Town Center, Gateway Commons, and Stringtown Rd. Extension. Although composite samples were successfully collected, there were still inherent problems for each project. Aerial photos and site plans with sampling locations are provided in the Technical Appendix.

Sediment Basin #3 Clarksburg Town Center (Clarksburg SPA)

Sediment Basin #3 was monitored for TSS during construction of Phase II-B of Clarksburg Town Center. Monitoring of this structure began in March 2005 and will continue until the structure has been converted to a SWM BMP. Sampling difficulties encountered include determining the necessary sampling locations to account for all stormwater inputs as well as accounting for the flow caused by groundwater.

Because the groundwater entering the structure made it difficult to determine when all the runoff from a storm is discharged, staff decided to measure flows leaving the structure for a consistent time span. On average, one round of sampling has lasted for 40 hours after the end of the storm, even though flows have continued for up to twenty days after a rain event.

Data is available for eight storms for Sediment Basin #3 (Table 3.1). The data from the eight storms indicate the structure was consistently effective at trapping sediment. However, continued flows of groundwater through the structure can slowly carry enough sediment to reduce the efficiency of the structure. Table 3.2 provides data for three sampling events in 2005 where monitoring was extended to account for continuous flow from the outlet. Comparing the data in Table 3.2 to the data for the same dates in Table 3.1 shows a decrease in efficiency as monitoring was extended. Therefore, results should be used cautiously when interpreting the efficiency of the structure and the TSS loading delivered to the stream from individual storms.

Table 3.1. Sediment loadings: Clarksburg Town Center Phase II-B Sediment Basin #3.

Date of Event	Rain (in.)	Rainfall Duration (hours)	TSS Loading (lbs)		TSS Reduction
			Inlets	Outfall	
4/30/2005	0.82	22.25	520.7	29.4	94%
5/19/2005	1.04	14.15	366	43.2	88%
5/23/2005	0.84	29.25	146	17.5	88%
5/11/2006	1.76	13	342.1	196.7	43%
6/1/2006	0.45	9	1180	37.1	97%
9/1/2006	1.95	31.58	3.1	4.4	-44% **
12/22/2006	1.3	15.67	108.4	14.3	87%
3/15/2007	2.09	47	87.2	4.3	95%
Mean			**344.2**	**43.4**	**68%**

** - Outlier – The negative TSS reduction during the September 1, 2006 storm was most likely due to low TSS concentrations in the runoff and resuspension of sediment in the trap.

Table 3.2. Total suspended solids loadings and percent difference observed during extended sampling: Clarksburg Town Center Phase II-B Sediment Basin #3.

Date of Event	Rain (in.)	Rainfall Duration (hours)	Duration of Extended Outfall Sampling (hours) *	TSS Loading (lbs)		TSS Reduction
				Inlets	Outfall Extended Sampling	
4/30/2005	0.82	22.25	339.6	520.7	89	83%
5/19/2005	1.04	14.15	88.75	366	68.5	81%
5/23/2005	0.84	29.25	170.5	146	34.3	77%

Sediment Basin #2 Gateway Commons (Clarksburg SPA)

Monitoring for TSS at Sediment Basin #2 was conducted from April through October 2006. Monitoring commenced over one year after the start of construction. All four samples were collected after roads and storm sewers were in place and the site was stabilized in February 15, 2006. Monitoring was delayed because of the need to finalize the basin configuration and to direct overland flows to the basin. Additionally, construction activities ceased in March 2006 while an additional plan was reviewed; therefore, no monitoring of TSS occurred in 2007 for this project.

The data available from the four storm events show very low TSS concentrations entering the structure (Table 3.3, Station #1). While the automated samplers successfully collected samples at Station #2 during the April and May storms, no flow could be captured during the two September storms. A lack of flow leaving the first cell suggests that runoff is infiltrating and nothing is entering the second cell. Similarly, the automated samplers at the outfall of the lower cell (Station #3) did not collect any samples during the four monitored storm events, suggesting that very little, if any, flow left the structure. The ability of the trap to contain all the flow and sediment from these storms (with rainfall between 0.79 to 1.95 inches) suggests that the structure was functioning well. However, this should be approached with caution: such performance may in part be due to the compacted soils and relatively sediment-free water entering the system (since monitoring occurred after mass grading and site stabilization) and because no flow was exiting the structure. It is also possible that efficiencies would vary under higher rainfall levels and as construction recommences.

Table 3.3. Sediment Loadings: Gateway Commons Sediment Basin #2.

Date of Event	Storm Characteristics			TSS Loading (lbs)			TSS Reduction	Discharge Volume (CF)	
	Rain (in .)	Rainfall Duration (hours)	Rainfall Return Interval	Station #1 (Upstream of Upper Cell; Inflow)	Station #2 (Between upper and lower cell)	Station #3 (Outfall of Lower Cell)	Station #1 to Station #2	Station #1	Station #2
4/21/2006	1.11	40.67	< 1 yr	18	3.4	n.a.	81%	127,646.40	4,598.40
5/11/2006	1.76	13	< 1 yr	10.6	0.8	n.a.	92%	37,628.40	3,286.50
9/1/2006	1.95	31.58	< 1 yr	0.3	n.a.	n.a.	n.a.	21,450.60	n.a.
9/28/2006	0.79	5.5	< 1 yr	2.4	n.a.	n.a.	n.a.	6,084.60	n.a.
Average							**87%**		

n.a. = not applicable (no flow collected)

Other Projects

Sample collection for the largest S&EC structure, Sediment Basin 3, for Stringtown Road Extension (in the Clarksburg SPA), began in 2006 and is ongoing. Difficulty obtaining the necessary flow for the sediment basin being monitored and similar weather-related challenges has made sampling challenging and delayed data submission. The preliminary data and results submitted indicate the structure is effective in reducing TSS loadings (Table 3.4). Storm event data (amount, duration, interval, etc.) was not provided by the consultant; therefore, a complete evaluation can not be provided at this time.

Table 3.4. Sediment Loadings: Stringtown Rd. Extension Sediment Basin #3.

Date of Event	TSS Loadings (lbs)		Percent Reduction	Discharge Volume (CF)	
	Inlet	Outfall		Inlet	Outfall
9/1/2006	1.513	n.a.	n.a.	7851.6	n.a.
9/28/2006	7.869	n.a.	n.a.	1612.2	n.a.
3/15/2007	326.613	2.095	99%	1105590**	10872
4/11/2007	1.049	0.118	89%	2917.1	655
6/28/2007	75.485	0.031	100%	3457	269
12/2/2007	0.379	0.021	94%	1843	811

** Upstream discharge for 3/15/2007 event is inaccurate due to backwater in pipe.

Two other projects in the Clarksburg SPA are in the process of collecting automated composite samples. Additionally, loading data will be obtained as construction begins for a number of projects. Several developments are anticipated to begin construction in 2008 and early 2009, most of which require monitoring of S&EC TSS using automated samplers (Technical Appendix). BMP efficiency during the construction (S&EC) phase will be better assessed as more automated sampling data is obtained.

3.3 Stormwater Management (SWM) BMP Monitoring

Post-construction BMP monitoring evaluates the efficiency of SWM BMPs. The BMPs in the SPAs are configured in redundant treatment trains to optimize performance. A diagram of a labeled SPA site plan with redundant SWM BMPs is provided in the Technical Appendix. Post-construction monitoring cannot begin until the construction on the property is complete, the site is stabilized, and the S&EC structures are converted over to SWM structures. Post-construction monitoring begins once the SWM structures are inspected and approved, and can extend up to five years on large projects.

As discussed in Section 1.3, the data available for evaluating SWM BMP pollutant load removal efficiency is limited. Four development projects within SPAs are fully completed, stabilized, and have had S&EC structures removed and replaced by permanent SWM structures. These projects are Willow Oaks (Piney Branch SPA), Running Brook (Clarksburg SPA), Cloverly Safeway, and Snider's Estates (Upper Paint Branch SPA). Flow-weighted data from three of the four projects are discussed in this report. Running Brook has had monitoring problems and has no useful flow-weighted data at this point. Additional information, figures, and data for Willow Oaks, Snider's Estates, and Cloverly Safeway are provided in the Technical Appendix.

Data is collected by using automated samplers to collect flow-weighted composite storm samples. Although not as difficult as sediment control structures, monitoring SWM structures is quite challenging. Ponding or backwater issues, equipment failure, or flow measurement distortion have continued to limit the amount of available flow-weighted composite data that is evaluated for BMP efficiency of SWM ponds. Data collection was limited in 2007 due to the lack of rain.

3.3.1 Surface Sand Filter

Background

A surface sand filter is a media filter. It is best-suited for managing the high concentration of pollutants in the volume generated by the first inch of rain (also known as the first flush). The Montgomery County Sand Filter is essentially a shallow, dry stormwater management facility which incorporates a sand filter and an underdrain. Pre-treatment is provided by a grass filter strip or other structural means (MCDPS 2007).

The sand filters are designed to include a recharge area beneath the filter medium and underdrain pipe to promote infiltration into suitable soils. The water remaining in the structure below the level of the underdrain pipe will percolate into underlying soils with suitable infiltration rates. SPA performance goals encourage the use of infiltration to reduce storm flow runoff and recharge groundwater to help maintain stream baseflows.

Sand filters have a range of removal efficiencies and are generally effective at removing total suspended solids, with removal efficiencies of 66 to 95% reported in the literature (Technical Appendix).

Willow Oaks (Piney Branch SPA)

Willow Oaks is an 8 acre, 14 single family lot cluster option development located on the eastside of Travilah Road, opposite Stonebridge View Drive. 6.9 acres of the development is sited within the Piney Branch SPA.

The stormwater management for this portion of the development is provided through an existing SWM pond in the Willows of Potomac subdivision (Pond 2) located upstream of the sand filters. This pond provides detention of the two year storm with a pre-developed release rate. Quality control is provided by a treatment train consisting of two surface sand filters in series (Technical Appendix). Vegetated filter strips provide pretreatment for the surface sand filters located upstream.

Monitoring of metals, nutrients, and suspended solids is required at three locations: 1) upstream of the first sand filter, after the vegetated strips; 2) after exiting the upper sand filter; and, 3) at the outlet of the second sand filter cell. Automated samplers are used to collect storm samples 4 times per year to assess the efficiency of the BMP at reducing loadings of selected pollutants. Sampling began in July 2005 and the last required storm of the 15 was captured in October 2007.

Table 3.5 provides BMP efficiency results for 5 storms where *influent* flows and *effluent* flows and could be captured and loadings could be calculated. Data from 3 other captured storms (July 7, 2005, October 24, 2005, and September 28, 2006) were not considered due to erroneous downstream flow rate values. The average pollutant loading reduction rates are above 90% for these storm events, when pollutant concentrations were above the detectable limit. Overall loadings for cadmium, lead, and nitrite were not calculated due to the prevalence of below-detection limit concentration results. Additional information regarding the efficiency calculations can be found in the Technical Appendix.

Table 3.5. Willow Oaks BMP Pollutant Load Reductions. Load reductions were calculated by examining the total load entering the system (two sand filters in series) with the total load leaving.

Storm Date	Copper	Zinc	Nitrate	TKN	Total Nitrogen	TSS
1/22/2006	89%	95%	94%	89%	91%	86%
4/21/2006	94%	97%	86%	96%	93%	88%
10/17/2006	96%	98%	98%	n/a	98%	99%
11/16/2006	n/a	n/a	98%	n/a	98%	97%
4/11/2007	89%	88%	78%	n/a	86%	99%
Mean	**92%**	**95%**	**91%**	**93%**	**93%**	**94%**

The data suggest that the series of vegetated filter strips and two surface sand filters were achieving high pollutant removal efficiency success for the evaluated storm events. All storms evaluated were smaller than *1-year storm* events (Table 3.6). Larger precipitation events could influence the BMP performance.

Table 3.6. Storm event data for the five storms used to evaluate Willow Oaks BMP pollutant load reductions efficiency.

Storm Date	Rainfall Quantity (in.)	Rain duration (h)	Return interval (y)	Total flow volume (m^3)		
				Station #1 (entrance to upper sand filter)	Station #2 (exit of upper sand filter, entrance to lower)	Station #3 (Outlet of lower sand filter)
1/22/2006	0.8	14.5	< 1	2,737	410	293
4/21/2006	1.51	26.75	< 1	2,649	2,984*	269
10/17/2006	0.74	9	< 1	1,161	73	37
11/16/2006	1.6	7.75	< 1	3,887	8,337*	99
4/11/2007	0.72	7.25	< 1	723	57	85

* Inaccurate flow rate measurement due to ponding in weir at Station #2

The BMP's ability to reduce flow levels to the point where almost all flow, and subsequently pollutants, were contained in the first sand filter contributed to high BMP performance. The sand filter promoted infiltration and storage and, with the help of the vegetated filter strips in the upstream treatment train, likely contributed to the good performance of this BMP.

Snider's Estates (Upper Paint Branch SPA)

The 8.1 acre Snider's Estates subdivision on Snider Lane, between New Hampshire Road and Good Hope Road, consists of six residential lots and a 0.72-acre parcel for SWM. SWM consists of a sand filter and two dry ponds in series. Storms greater than the one to two year design storm overflow directly from the upstream pond into the downstream pond via a riser that leads to an inter-basin pipe. In addition to managing on-site storm flow, the SWM structures also treat an additional 24,000 square feet of impervious area along Snider Lane (west of the site).

The purpose of this monitoring was to evaluate if the structures reduced flows to the level estimated by the design model. The scope of the monitoring was limited due to the limited amount of development. Monitoring of continuous storm flow was conducted at the Pond 1 outfall (Technical Appendix). Performance of the SWM facility was evaluated by comparing measured pond outflows with TR-20 design-storm simulated events.

Post-construction monitoring to evaluate BMP effectiveness in diverting and absorbing storm runoff commenced in December 2004 and concluded in late 2007. Fifteen (15) storms were captured and characterized (Technical Appendix). Six of those storms with return intervals greater than one year and could be compared with the TR-20 model simulated responses to test whether the pond was functioning as designed (Table 3.7). The peak flows from two storms (January 14, 2005 and July 7, 2005) exceeded the expected range while the other evaluated storms fell within the expected range, suggesting that the BMP is functioning as designed. However, it is not possible to evaluate if other factors such as a decrease in annual rainfall and accompanying extended dry periods or the growing lawns and vegetation from the residential lots influenced BMP performance. Measuring the peak flow rate at the inflow of the structure and where flow bypasses Pond 1, examining *catchment* land use factors, and measuring the peak flow at the outfall of Pond 2 would be needed to fully evaluate the effectiveness of the sand filter and infiltration trench at retaining storm flow and in order to evaluate the SWM facility as a whole.

Table 3.7. TR-20 measured storm results for peak flow at Snider's Estates SWM pond 1 outfall.

Storm Date	Storm Rainfall (in.)	Storm Duration (hr.)	Storm Frequency (yr.)	Observed (Measured) Peak Flow Rate (CFS)	Expected (Controlled) Peak Flow range (CFS)
1/14/2005	2.0	6.8	1	4.6	0.1 – 0.8
7/7/2005	2.9	15.2	2	5.0	0.1 – 1.4
10/7/2005	6.1	22.5	25	3.6	1.8 – 4.0
6/25/2006	6.8	9.1	200	10.7	4.8 – 13.7
6/13/2007	2.0	2.1	5	0.7	0.0 – 2.5
10/24/2007	4.4	77.3	2-5	0.1	0.2 – 2.5

3.3.2 Stormceptor® Results

Background

A Stormceptor® (hereafter "Stormceptor") is a *hydrodynamic device*. Hydrodynamic devices use the flow and direction of water to remove pollutants. The Stormceptor is designed to treat a maximum flow rate and bypass the remainder of the runoff volume. The Stormceptor slows incoming stormwater to reduce turbulence, which allows oils to rise and sediment to settle.

A study by the Massachusetts Strategic Envirotechnology Partnership (STEP 2003) that monitored two Stormceptors, found that the Stormceptor removed between 52% and 77% of TSS, which is lower than the 80% targeted by the manufacturer (Rinker Materials 2008). A report by the Center for Watershed Protection (RAC 2002) cited performance of Stormceptors between 21% and 51.5% removal of TSS. More materials on the Stormceptor are provided in the Technical Appendix.

Cloverly Safeway (Upper Paint Branch SPA)

The Cloverly Safeway is located on New Hampshire Avenue; part of this site falls within the Upper Paint Branch SPA. BMP monitoring on this project consists of evaluating the efficiency of a Stormceptor in the reduction of pollutant concentrations and loadings during storm events as well as monitoring and assessing the effluent for the presence of temperature increases.

Other BMPs upstream of the Stormceptor consist of stormwater storage underneath a parking area and a *bioretention structure* adjacent to the southern section of the parking area. Stormwater runoff enters the stormdrain system through three curbside inlets in the parking lot (one located at the entry from Briggs Chaney Rd. and the other two along Gallaudet Ave.), and from two overflow inlets sited in the bioretention facility located between Briggs Chaney Rd. and the parking area. Excess water from the bioretention area is piped underneath the parking area to join the direct runoff from the three curbside inlets. The runoff then enters a storage area, which consists of a network of pipes underneath the parking area. Water from the storage area drains to the Stormceptor inlet via a control structure.

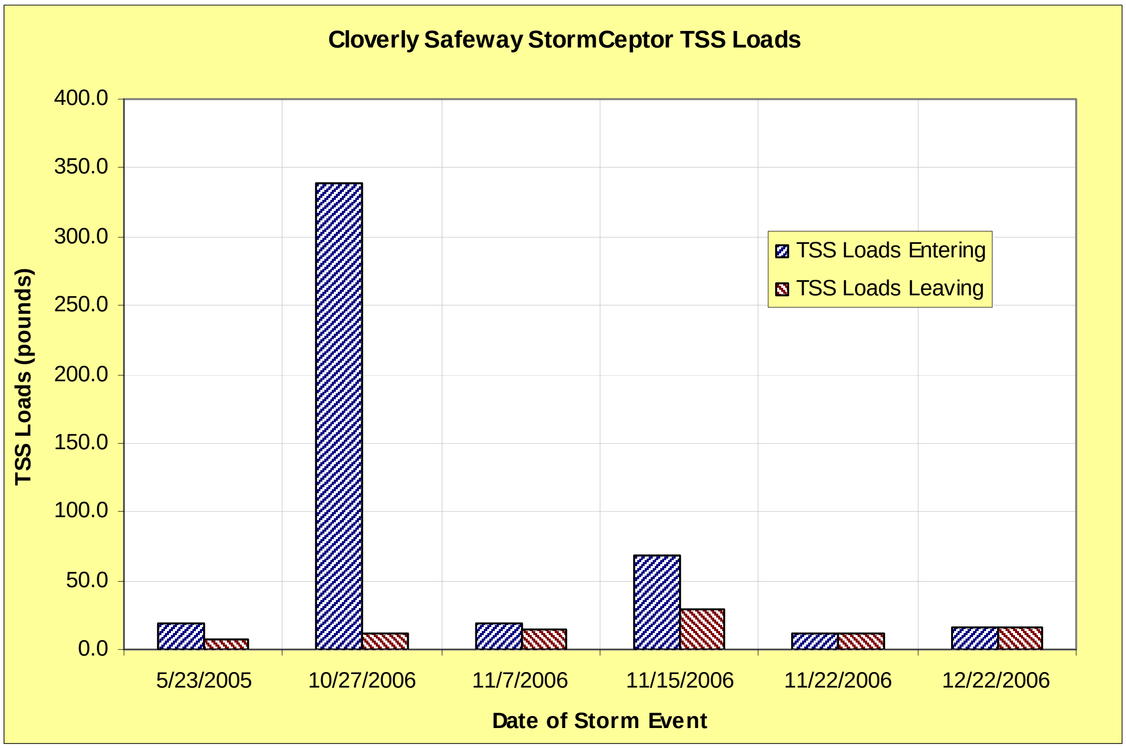
The Stormceptor functions as additional quality control in the treatment train. Flow-weighted samples of cadmium, copper, lead, zinc and total suspended solids, along with a petroleum hydrocarbon grab sample from the first portion of each storm, are collected from locations before and after stormwater passes through the structure (Technical Appendix). The Cloverly Safeway project has been monitoring the Stormceptor since May 2003 and will continue through 2008. Weather-related challenges and mechanical difficulties prevented acquisition of data for 2007 (the December 2007 storm was collected in fulfillment of 2006's requirement of 3 storms per year). A total of 11 storm events of the required 15 have been captured.

In general, monitoring activities to date showed that the Stormceptor had some tendency toward reduction in pollutant loadings where pollutant concentrations were high entering the structure. In some cases, there was an increase in the loading leaving the structure. A potential contributing factor to increased loadings leaving the structure is that the water entering the Stormceptor also contained relatively low concentrations of pollutants. The bioretention structure upstream of the Stormceptor provides quality control, using plants and soils to remove pollutants from the stormwater. Many storm samples had pollutant concentrations below the detectable limits. It is difficult to improve on water quality that already has a low pollutant concentration.

Total suspended solids, on the other hand, were often present in high enough concentrations entering and leaving the structure so that loadings could be calculated and evaluated. The Stormceptor seemed to work well at reducing TSS loadings between the inlet and outlet during one event (October 27, 2006) and successfully reduced TSS loadings for three others (Fig. 3.8). However, the storm event on November 22, 2006 and subsequent events show no difference between the TSS loadings entering the structure and leaving it. At this time, there does not appear to be a clear trend between performance of this structure and characteristics of the captured storm events. See the Technical Appendix for storm data.

Although only preliminary, some data was submitted in fulfillment of the remaining required storm for the 2006 monitoring and the three required for 2007. Loading calculations for the inlet and the outlet were obtained for a storm in December 2007 and two in March 2008 (Table 3.8). These events are discussed separately because storm summaries and flow volumes and rates have not yet been reported by the consultant. Examination of the loadings entering the structure and leaving the structure reveals a decline in the performance of the Stormceptor. The December 2007 storm sample showed the same load of TSS leaving the Stormceptor as entering it. The two storm events captured in March 2008 show more TSS leaving the Stormceptor than entering. One possible reason for the poor performance is that the structure has not been cleaned or maintained.

Grab sample monitoring of total petroleum hydrocarbon (TPH) during first flush revealed that TPH was entering and leaving the system in very low concentrations, most often below the detectable limit.



*No TSS loads are available for storm events pre-dating May 23, 2005.

Figure 3.8. Cloverly Safeway Stormceptor Loads.

Table 3.8. Cloverly Safeway Stormceptor TSS loadings for recent storm events. No storm data is available for analysis.

Storm Event Date	TSS load (lbs)	
	TSS Loads Entering	TSS Loads Leaving
12/15/2007	13.9	13.9
3/4/2008	21.3	26.6
3/7/2008	4.7	8.7

Temperature was also monitored downstream of the Stormceptor. For eight of the events, runoff temperatures spiked upward between approximately 3° (September 28, 2004) and

18° (November 22, 2006) Fahrenheit at the inception of the storm events. Temperature response was inconclusive for the remaining two events (April 12, 2004 and November 15, 2006). The most recent temperature data available is from the December 22, 2006 event. The runoff temperature rose approximately 7° Fahrenheit at the inception of the storm. The Stormceptor is not designed to mitigate thermal impacts, and other BMPs, which promote infiltration and help to mitigate thermal impacts such as bioretention to work in conjunction with the device.

3.4 Discussion of Structural Monitoring of S&EC and SWM BMPs

Very little data is available for evaluating the efficiency of S&EC basins at capturing total suspended solids. The majority of the BMP efficiency data cited in scientific literature is for pollutant removal efficiency of SWM BMPs.

Although more research is needed to reveal factors that cause a S&EC or SWM structures to function well or poorly, several variables have been identified by DEP as sources of disparity (CWP 2007), including:

- the amount and type of sediment disturbing activities occurring at the site at the time of sampling;
- the number of storms sampled and the characteristics of each (i.e. rainfall and accumulation, duration, flow rate, particle size of each);
- the monitoring technique employed;
- the internal geometry and storage volume and design features of the structure; and
- the size and land use of the contributing catchment.

The concentration of pollutants in runoff (i.e. how dirty it is) can influence the actual pollutant removal percentages. If the concentration is near an *irreducible level*, such that it is near or below a detectable limit, a low or negative removal percentage can be recorded (Schueler 2000).

Efficiency alone does not provide the entire picture to how well a BMP is performing; evaluating the mass of pollutants leaving the structure and entering the stream is also an important criterion. With these factors in mind, great care should be taken, not just when examining the County’s results alone, but when trying to make comparisons between S&EC BMPs employed locally and nationally.

The SWM BMPs monitored showed variable performance based on the technology sampled and the location of the BMP in the treatment train. The stormwater BMPs evaluated in this report were not located in the Clarksburg SPA. The evolution of development in Clarksburg, from an undeveloped rural environment to a dense suburban/urban environment makes it a perfect test site to evaluate the ability of structural BMPs to protect water quality. All the other SPAs (with the exception of Upper Rock Creek) were fairly well-developed prior to being adopted as a SPA, making it more difficult to parse out the effects of additional development from those areas already developed. Ultimately, a conclusive evaluation of the effects on development cannot be completed until the watershed is built out or almost build out.

Additionally, DEP and DPS are taking several steps to improve consultant success at collecting automated flow-weighted composite samples at S&EC structures and to help minimize impacts during construction:

1. As of 2008, individuals conducting SPA BMP monitoring will be required to submit quarterly progress reports detailing whether monitoring is on schedule and what problems have been encountered;

2. More field meetings and planning prior to commencement of monitoring will be conducted; and

3. S&EC BMPs will be converted to SWM BMPs once the drainage area to the structure has been stabilized.

As stated previously, evaluating BMP efficiency by presenting percent removal is one important assessment tool. Measuring changes to stream geometry, habitat, and chemistry (Section 4), and ultimately the biological community (Section 5) are also examined as indicators of BMP effectiveness to protecting water quality.

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4. Stream Characteristics

Forecasting the effects of urbanization on stream ecosystems is an enormous challenge, as it requires an integration of knowledge from numerous disciplines, including hydrology (Nilsson et al. 2003), geomorphology, and remote sensing. The County has been reporting on changing biological stream conditions for over ten years as a cost effective method to document the cumulative impacts occurring in SPA streams. However, in order to link these biological changes to changes in stream hydrology, *stream morphology*, and habitat, a comprehensive ecological monitoring and assessment approach is needed. Applying an extensive ecological monitoring and assessment approach across all SPA watersheds is beyond the ability of the County. Therefore, the County formed an integrated monitoring partnership to study the changes that will occur in the Clarksburg Master Plan SPA (Section 1.4). The partnership of Government agencies and universities has concentrated their resources on Clarksburg because:

- of the ability to evaluate the effects of development on an undeveloped landscape,
- the level of development activity is greatest,
- the suite of representative BMPs to monitor is the most diverse, and
- long term monitoring resources enable the most intensive and effective monitoring to evaluate changes in hydrology and morphology.

Results from this effort will be used to evaluate which BMP types are the most and least effective. This information then can target the most effective BMPs to new development activities in the other SPAs and elsewhere throughout the County. This monitoring effort will also address the Clarksburg Stage 4 monitoring requirements.

In order to account for natural variability, a *paired catchment (watershed) design* is helpful (Farahmand et al. 2007) and was incorporated into the Clarksburg monitoring study design. The same measurements will be collected in drainage areas undergoing development as well as drainage areas that remain undeveloped. Changes due to natural variability as opposed to development impacts will be identified. Good stream flow data from well maintained stream gages will be essential to adequately describe these hydrological changes (Booth and Jackson 1997; Bledsoe 2001). The following sections present information on landscape changes, hydrology, geomorphology, water quality, and habitat.

4.1 Landscape Changes in the Newcut Road area of Clarksburg

LiDAR (Light Detection and Ranging) is a remote sensing method used to collect topographic elevation information at very high resolutions (with a vertical precision of six inches or less). LiDAR is recorded via aircraft mounted lasers capable of recording 2,000 to 5,000 elevation measurements per second. The resulting imagery is much more precise than that of conventional aerial photography (NOAA 1999).

LiDAR imagery has been captured by the U.S. Environmental Protection Agency (EPA), Landscape Ecology Branch (U.S. EPA LEB) for the first areas developed in the Newcut

Road neighborhood. These areas are the neighboring properties of Greenway Village (Phases 1 to 4), and Clarksburg Village (Phases 1 and 2). Greenway Village is on the right of the image, and Clarksburg Village is on the left (Fig. 4.1). The stream divides the developments. LiDAR was successfully taken in 2002, 2004 and 2007 by U.S. EPA LEB (Figs. 4.1, 4.2, and 4.3).

The 2002 coverage (Fig. 4.1) recorded pre-construction topography of the area. Before construction activities began, the landscape consisted of gently to moderate rolling slopes and land use was predominantly farmland. The small stream draining this area can be seen in the middle of the image. Springs and seeps can be observed at several headwater areas of this stream. Surface runoff would be conveyed into the stream through natural drainages and *ephemeral stream* channels. Groundwater recharge is conveyed through the existing springs and seeps to maintain the baseflow of the stream. Overall imperviousness was low, allowing for stormwater infiltration into the ground.

The LiDAR image taken in 2004 (Fig. 4.2) documents changes that occurred to the topography and natural drainage patterns from the cutting and filling required to bring the site into leveled and approved grades for lots, roads, and utilities. The road grade requirements of 4% maximum slope directly influence the cut and fill necessary to balance the developer's onsite excavation and avoid the cost of importing soil. This massive movement of soil can have lasting effects on the water quality due to changes in the basic flow regime of the stream and ground water (CWP 2003; Konrad and Booth 2005).

On the east side (Greenway Village), distinct cut lines along the limits of disturbance document the new elevations graded into the development. The rolling topography was smoothed and leveled, altering the natural drainage patterns. Newly installed S&EC BMPs can be seen installed at the lower elevations of the new topography with some of the BMPs sited at the heads of springs and seeps.

The last LiDAR image shows the development through 2007 (Fig. 4.3). Final grades can be seen throughout the site as the rolling topography has been cut, graded, smoothed, and leveled. Snowden Farm Parkway, a major connecting road, is seen in the middle of the image, bordering the headwater stream for much of its length. Grading for the parkway and S&EC BMPs bisect the natural drainage patterns on the left side of the image, potentially impacting the springs, seeps, and recharge areas on this side of the stream. Newly-defined channels across the floodplain from the S&EC BMPs are shown in the 2004 and 2007 images. The natural drainage patterns on the right side of the image have also been eliminated, and runoff from the new impervious surfaces is redirected into the stormdrain system. An unanticipated impact was also recorded in this imagery sequence. Sewer service is provided to the developments through gravity fed lines and several segments of the sewer line required blasting. The fill from these segments are shown to have subsided after completion of the line. The proximity of the sewer lines running parallel to the stream have the potential to intersect groundwater recharge to the stream. The overall topography, natural drainage patterns, and natural infiltration have been altered due to the cut and fill requirements necessary to meet the density requirements of these neighborhoods and the diversion of most of the stormwater runoff into stormwater inlets and drains.

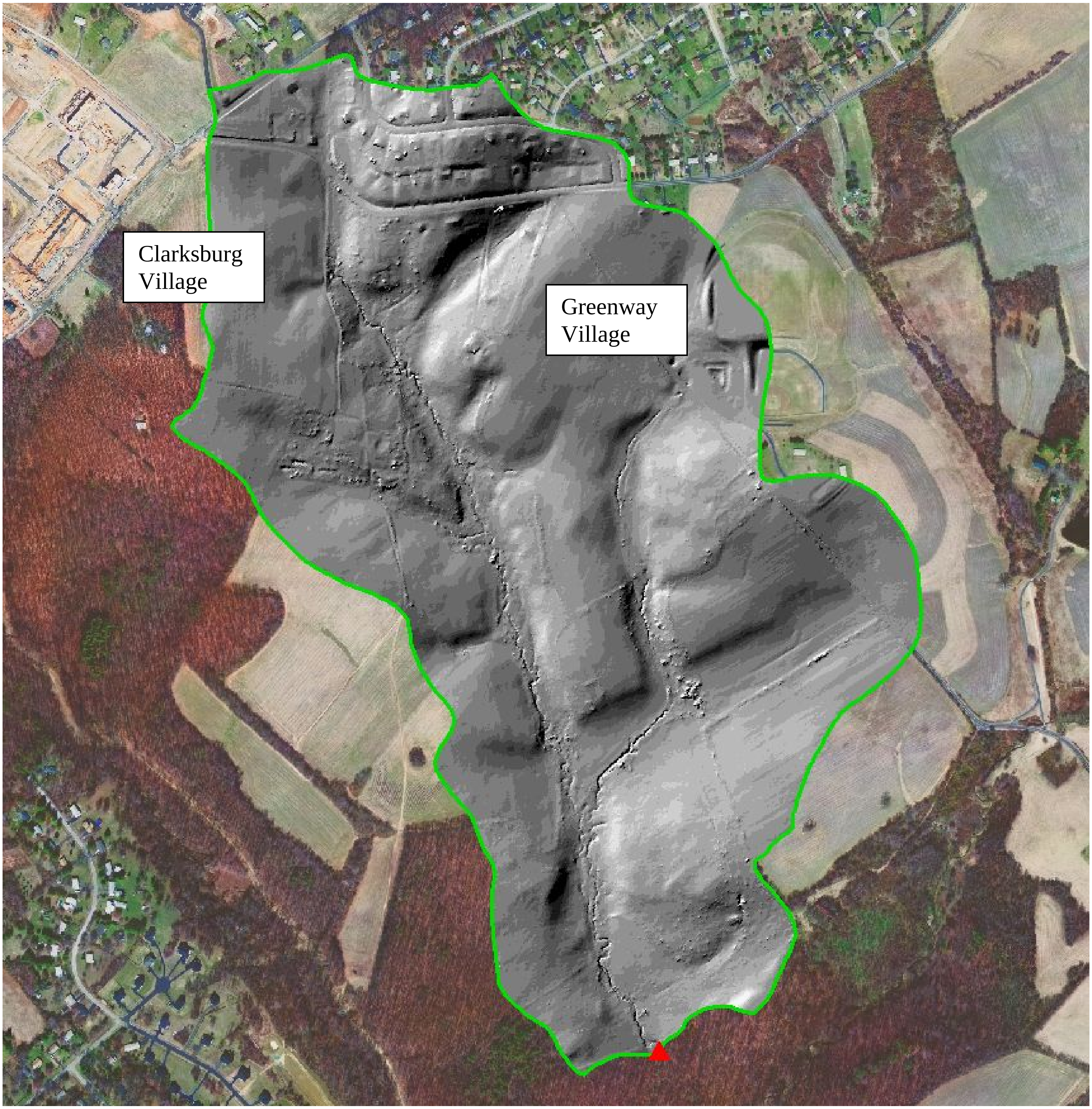


Figure 4.1. 2002 LiDAR Imagery of Newcut Road Neighborhood, Greenway Village, and Clarksburg Village (U.S. EPA LEB).

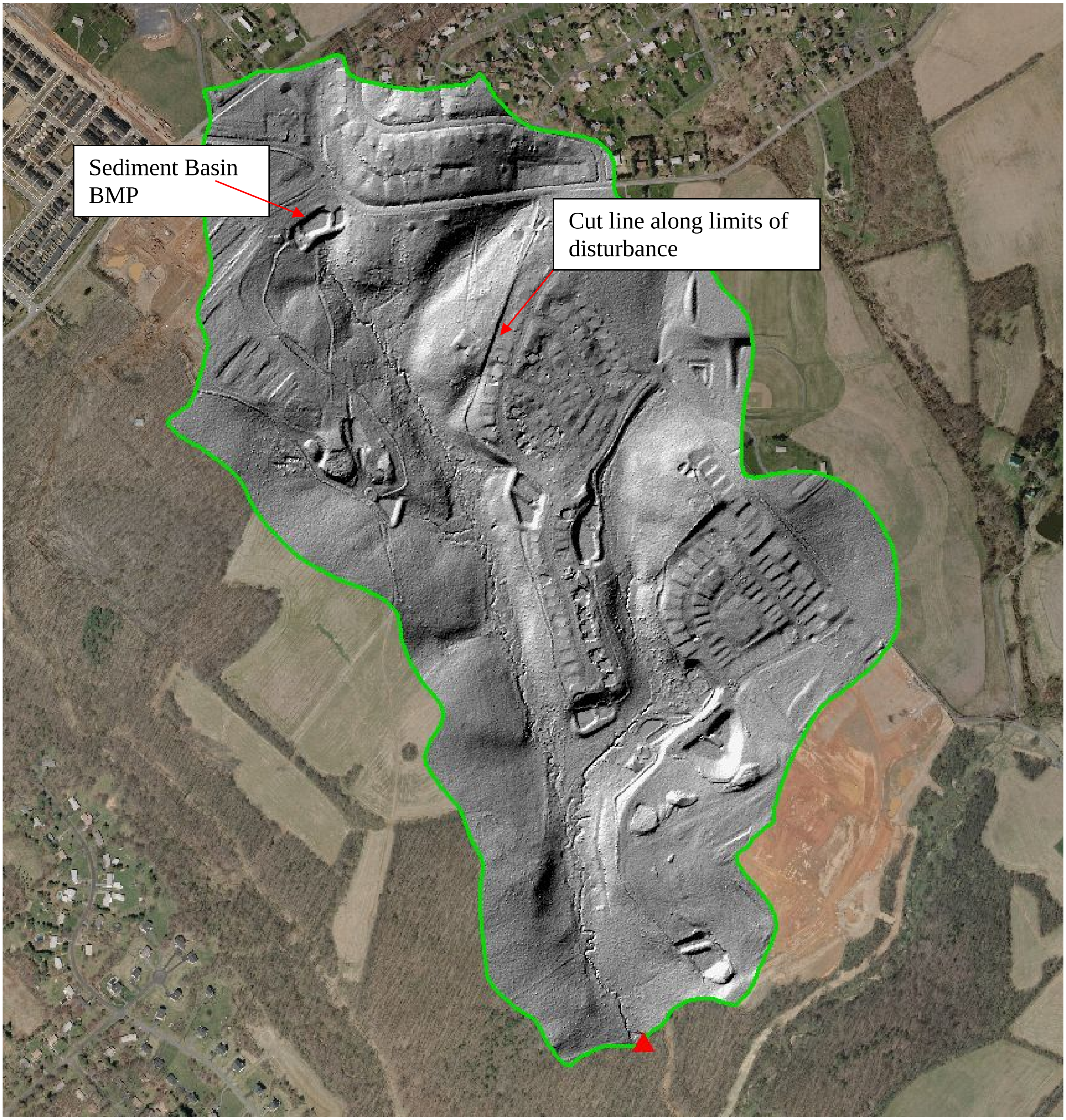


Figure 4.2. 2004 LiDAR Imagery of Newcut Road Neighborhood, Greenway Village, and Clarksburg Village (U.S. EPA LEB).

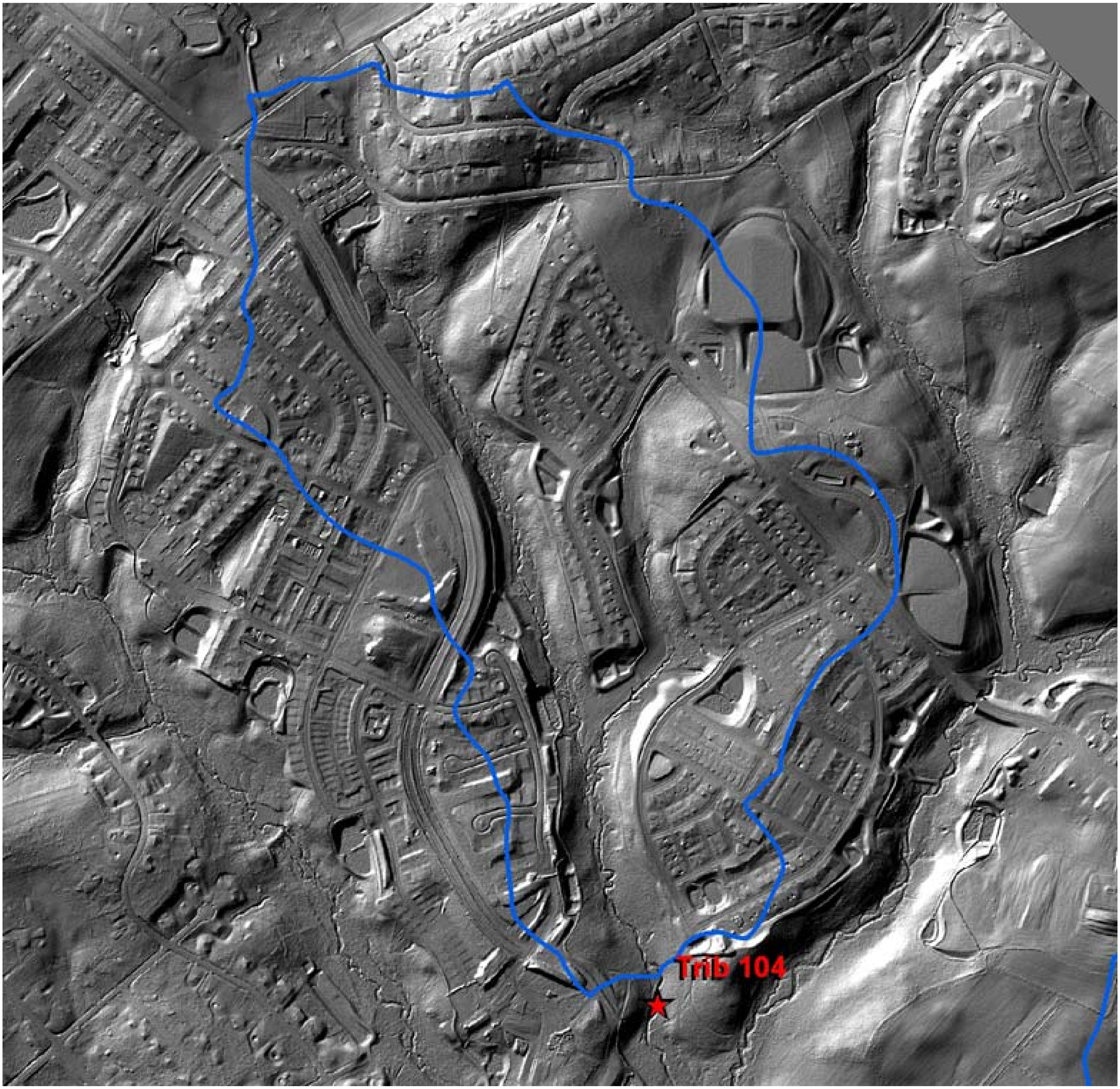


Figure 4.3. 2007 LiDAR Imagery of Newcut Road Neighborhood, Greenway Village, and Clarksburg Village (U.S. EPA LEB).

Overall cut and fill differences are readily seen in Figure 4.4. Black and red areas are cut and brown areas are fill. Final grades and imperviousness surfaces are on top of the cut and fill areas. The development areas outside the immediate stream buffers have had their surface grades altered, surface drainage patterns diverted into stormdrains, and the imperviousness greatly increased from pre-construction levels. The purpose of installing the SWM BMPs are to minimize impacts to the receiving streams through redundant structures that provide both quality and quantity controls such that post-construction release rates are equivalent to pre-construction rates.

The U.S. EPA LEB will be further analyzing the multi-year LiDAR imagery and plan to continue acquiring additional imagery as the development areas are completed. Once the developments have been completed and the S&EC BMPs have been converted to SWM BMPs, EPA scientists will be able to measure the change in stream cross-sections, profiles, and areas of increased deposition and erosion, and compare the changes to a control area within the Little Bennett Regional Park. DEP has also coordinated with the U.S. EPA LEB and other colleagues from the United States Geological Survey (USGS), Eastern Geographic Science Center to survey the accuracy of the LiDAR imagery to known control points so the changes DEP records in field surveyed cross sections and profiles can be precisely compared to the watershed-wide changes the LiDAR imagery captures.

The ground survey results will be compared to the continuing LiDAR data once the study has been completed through a joint study between the U.S. EPA LEB, University of Maryland, College Park, and DEP.

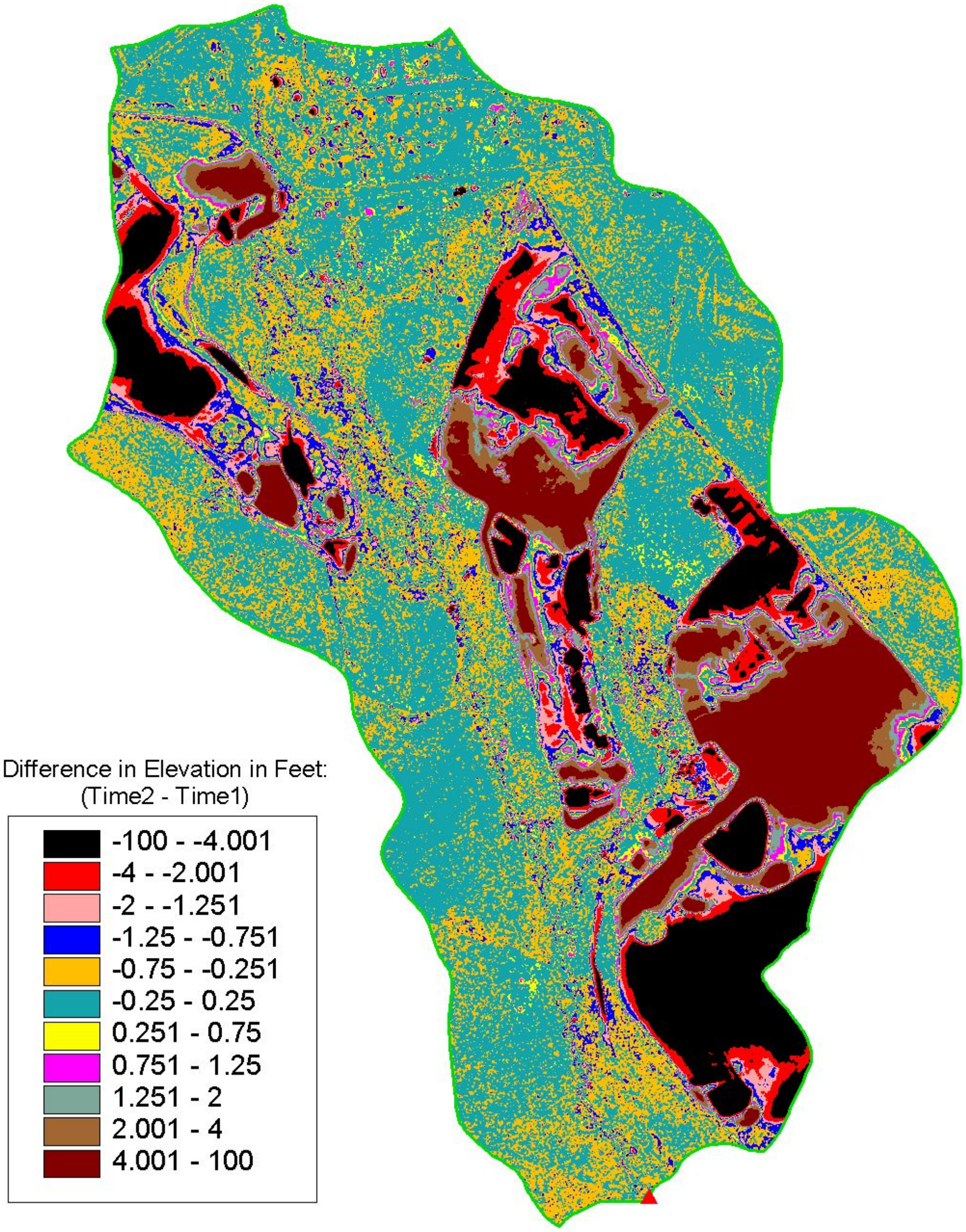


Figure 4.4. Total Cut and Fill Differences for the Newcut Road Neighborhood, Greenway Village, and Clarksburg Village between years 2002 & 2007

(U.S. EPA LEB).

4.2 Hydrology

4.2.1 Background

Conversion of watersheds to urban areas has been shown to have major affects on stream hydrology as a result of vegetation removal, stream channel modification, and increases in impervious area. These alterations can lead to flashier hydrologic responses: faster onset and decay of storm flow *hydrographs*, reduction in base flow rates, and higher and earlier peak discharges (Bledsoe 2001; Paul and Meyer 2001; CWP 2003; Goonetilleka et al, 2005; Konrad and Booth 2005; Walsh et al. 2005; Farahmand et al. 2007). The effects of these hydrologic changes are most severe in headwater streams (Nehrke and Roesner 2001).

The SPA SWM designs attempt to minimize storm flow runoff increases and maintain existing stream base flow. Redundant controls (treatment trains) are required for stormwater quality control. This is a challenging endeavor as the approved densities for a development may require the placement of the SWM quantity control BMPs to be on the margins of the development, with few opportunities to place enough SWM infiltration structures above the quantity control structure to mimic the diffuse and lengthy release of water into the stream as in pre-construction conditions.

The LiDAR time series records the multiple and cumulative watershed changes as a direct result of the development process in the Newcut Road Neighborhood and, by inference, other substantially similar developments in substantially similar watersheds. The loss of water storage capacity of the hill slopes that have been graded and leveled through urban development (such as shown in the LiDAR series), along with reductions in vegetative cover, topographic depressions, soil depths, and infiltration capacity of the native soils, lead to hydrologic changes (CWP 2003; Konrad and Booth 2005).

4.2.2 Study Design and Data Collection

In 2004, the USGS, U.S. EPA, and Montgomery County DEP cooperatively established five stream gages in the Clarksburg SPA as part of the Integrated Clarksburg Monitoring Partnership. Two rain gages were also established in the study area to record localized storm events (Fig. 1.3).

The purpose of the five gages is to document changes in stream hydrology as a result of the land use changes and urbanization that are ongoing in Clarksburg. Two of the gages are control gages: one in a substantially undeveloped drainage and one in a developed area with SWM BMPs predominately designed from the pre-2000 design manual. Three of the gages are downstream of areas that will have significant land use change and urbanization – two in the Newcut Road Neighborhood and one in the Cabin Branch Neighborhood. When development is completed and the SWM BMPs have been converted from S&EC BMPs, changes in storm flows, base flow, and peak discharges will be analyzed and presented. For the purpose of this report, the S&EC BMPs have not been converted to SWM BMPs and observations reported here are for the S&EC structures monitored during the construction period.

4.2.3 Hydrologic Data Analysis and Interpretation

The rain gages have produced records of rainfall totals that allow the calculation of a number of useful statistics including storm durations, storm mean intensity, and storm peak intensity. More detailed information is presented in the Technical Appendix and will be summarized here.

The stream flow gages have produced data that allows the calculation of instantaneous peak discharge and daily mean discharge. The Sopers Branch gage (01643395) and the Little Seneca Creek Tributary near Clarksburg, MD (Newcut Road neighborhood) gage (01644371) data are used in this report. The drainage area to the Newcut Road Tributary gage has had the largest amount of land disturbance relative to the development process than at any of the other four gages (Figs. 4.1. to 4.4.). Information on the five gages is presented in Table 4.1.

Table 4.1. Descriptions of the Five Stream Gages in the Clarksburg Study Area.

Gage Id. Number	Name	Date Started	DA (mi^2)	DA (acres)
01644371	Little Seneca Creek Tributary Near Clarksburg, MD	5/2004	0.43 mi^2	275.2
01643395	Sopers Branch at Hyattstown, MD	2/2004	1.17 mi^2	748.8
01644375	Little Seneca Creek Tributary Near Germantown, MD	6/2004	1.35 mi^2	864
01644372	Little Seneca Creek Tributary at Brink, MD	6/2004	0.37 mi^2	236.8
01644380	Cabin Branch Near Boyds, MD	6/2004	0.79 mi^2	505.6

Average annual precipitation is about 42 inches in the Baltimore-Washington area (NWS 2008). Average monthly precipitation varies throughout the year and spring and summer thunderstorms can cause significant variations in precipitation depending on location (Doheny et al. 2006; James 1986).

Annual runoff for the two USGS gages (01644371, 016433955) was provided by the USGS, Baltimore Office (E Doheny, 2008, personal communication) for calendar years 2005 and 2006 and used to determine how much average annual precipitation infiltrates into the groundwater or is released into the atmosphere through *evapotransporation*. Annual runoff at the control gage Sopers Branch at Hyattstown, MD was 16.62 inches in 2005 and 14.11 inches in 2006. On average, about 60 to 65% of the average annual precipitation at Sopers Branch either infiltrated into the ground or was lost to evapotransporation during calendar years 2005 and 2006.

Annual runoff at the test gage Little Seneca Creek Tributary near Clarksburg, MD was 15.44 inches in 2005 and 19.95 inches in 2006. On average, about 63% of the average annual precipitation at this tributary of Little Seneca Creek gage either infiltrated into the ground or was lost to evapotransporation during calendar year 2005. On average, about 52.5% of the average annual precipitation at this tributary of Little Seneca Creek gage either infiltrated into the ground or was lost to evapotransporation during calendar year 2006.

The annual runoff was also provided in USGS *water years* (October to September). Using the water year data provides three water years of information to compare the test and control stations. The Sopers Branch had about 62.5% of the average annual precipitation either infiltrating into the ground or lost to evapotransporation during water year 2005, 71.3% in water year 2006, and 55.1% in water year 2007. The tributary of Little Seneca Creek had about 66.8% of the average annual precipitation either infiltrating into the ground or lost to evapotransporation during water year 2005, 58.6% in water year 2006, and 46.71% in water year 2007. On average, the overall amount of stormwater infiltrating into the ground or lost via evapotransporation steadily declined in the Newcut Road Neighborhood Tributary. Figures 4.1 through 4.4 depict the land use changes that occurred within this drainage area during the same time period.

The overall amount of stormwater runoff directly entering the Newcut Road Neighborhood Tributary to Little Seneca Creek increased over this same time period. Annual flows were adjusted for the differing drainage areas of the two gages to normalize the annual runoff amounts and to allow for comparison. The adjusted annual flows are shown in Figure 4.5. More rainfall is running directly into the Newcut Road Neighborhood Tributary stream than Sopers Branch for the 2005, 2006, and 2007 water years (Fig. 4.5). This is likely due to the changes in imperviousness that have occurred in the drainage area as a result of development.

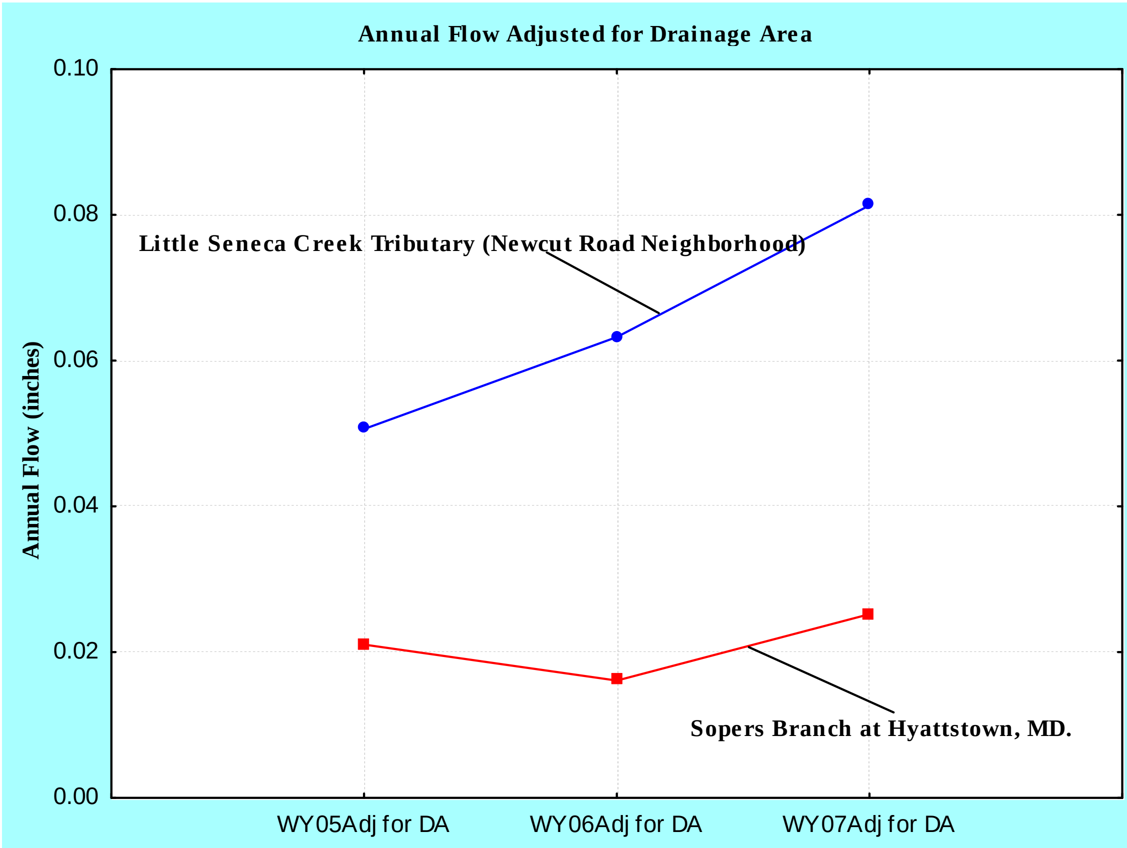


Figure 4.5. Annual Flow (adjusted for drainage area).

Conversion of watersheds to urban areas can lead to *flashier* hydrologic responses (Farahmand et al. 2007) with water levels that rise, peak, and fall very rapidly in response to storm precipitation (Doheny et al. 2006). An index has been developed to compare the flashiness of streams (Doheny et. al. 2006). The index is a ratio between the instantaneous peak discharge (highest stream flow) to the daily mean discharge (average stream flow) that occurs during a storm event. When the discharge is divided by the size of the drainage area (acres), the ratios are normalized and the ratios from different streams can be compared. Using this technique, the relative flashiness of specific storm events for Sopers Branch and the Tributary of Little Seneca gages were compared (Technical Appendix). When the conversion to SWM BMPs has been completed, this ratio will be used to determine if flashier hydrologic responses are occurring in the Newcut Road drainage. Figure 4.6 graphs the adjusted flashiness index for the two drainages for specific storms that occurred during 2004, 2006 and 2007. During the construction period, the Newcut Road drainage was, on average, flashier than the Sopers Branch drainage (Fig. 4.6). During the later drought period of 2007, the Newcut Road Tributary was noticeably less flashy.

Time of concentration is defined as the difference in time between the start of rainfall and when discharge begins to increase at the gaging station (Doheny et al. 2006). Changes in the time of concentration of a watershed can be useful in understanding stream response to increases in imperviousness. When the conversion to SWM BMPs have been completed, time of concentration will be evaluated to determine if the Newcut Road tributary's response to rainfall has been changed compared to the control station. At this point in the development process, time of concentration is similar between the Sopers Branch and the Newcut Road Neighborhood (Tributary of Little Seneca) gages (Technical Appendix).

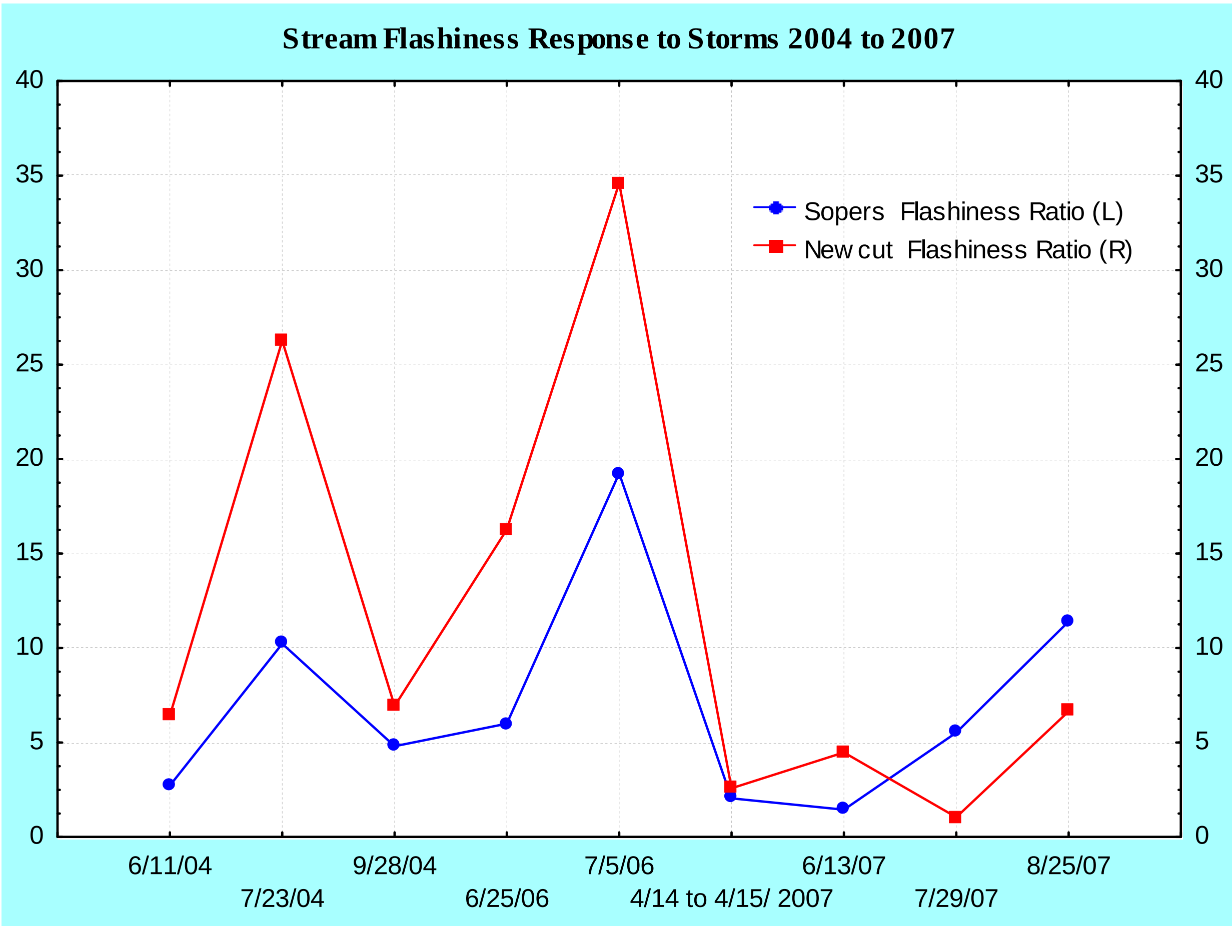


Figure 4.6. Comparison of Stream Response to Storm Events: 2004 to 2007.

On average, the Newcut Road tributary had a flashier response to storms before the drought period of 2007 due to less average annual precipitation infiltrating into the ground or being lost through evapotransporation, and more average annual precipitation running off directly into the stream. The Newcut Road Tributary has a similar time of concentration to that of the comparison gage station.

Changes in the storm runoff amounts, directly and immediately reaching the stream, and the flashiness of the stream's response to storms can cause changes in stream geomorphology.

4.3 Changes in Stream Geomorphology

Many studies have shown that impervious surfaces created as a result of urbanization are the primary cause of channel enlargement in suburban and urban areas. (Bledsoe 2001; Paul and Meyer 2001), (Fig. 4.7). The goal of the SPA SWM BMPs is to reduce storm flows to streams to predevelopment conditions. Streams are dynamic systems that adjust their geomorphology over time to the flows of sediment and water contributed by their watersheds (Bledsoe 2001). These adjustments are an effort to achieve a state of equilibrium as the morphology of a stream changes to compensate for increases and decreases in sediment loads.

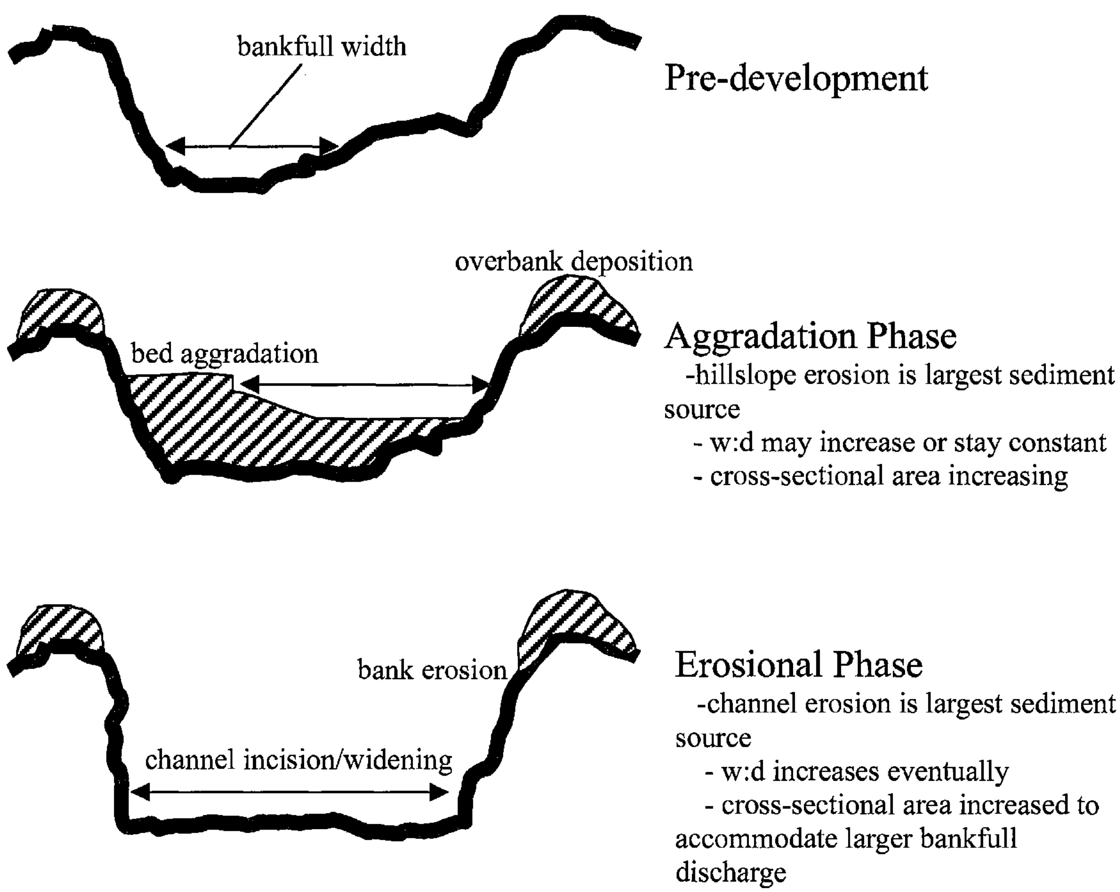


Figure 4.7. Stream channel changes as a result of development and increases in imperviousness (Paul and Meyer 2001).

Stream bed *aggradation* has been shown to occur with the construction phase, resulting in an increase in stream bed elevation as sediment fills the channel (Paul and Meyer

2001). For instance, if sediment accumulates in a stream, the bed of the channel is raised at that point, and the slope increases downstream of the deposit (Ritter 2006). An increase in the slope of the stream results in a higher velocity of flow that can erode and carry the sediment away (Ritter 2006).

4.3.1 Study Design and Data Collection

As described in section 1.4 and illustrated in Figure 4.8, monitoring efforts have been focused on the Clarksburg Master Plan SPA area. Geomorphic surveys are conducted in the three test areas: two in the Newcut Road Neighborhood (Little Seneca 104 tributary) (Fig. 4.9.a), and one in the Cabin Branch Neighborhood as well as in the undeveloped control area in Little Bennett Regional Park (Soper's Branch) (Fig. 4.9.b) and the developed control in the Germantown area (Crystal Rock) (Fig. 4.9.c). Multiple surveys were completed in all areas to document the temporal change in stream channel morphology. Survey information includes longitudinal profiles, cross sections, bed composition (pebble counts), and sinuosity.

Surveys are located within similar habitat sections of the study streams. The first habitat section is a steeply-graded, straight channel (low sinuosity index) consisting mostly of *riffle* habitat. As sections were surveyed further downstream (areas two, three, and four), the slope of the stream slightly decreases, sinuosity increases, and runs and pools become more prevalent.

4.3.2 Data Analysis and interpretation

Preliminary results are presented in the Technical Appendix for cross sections established in the most downstream sections within the Newcut Road Neighborhood test area (area 4), the Little Bennett control (Sopers Branch area 4), and the Germantown control (area 2). All cross sections used in this comparison were measured in riffle/run stream areas. Riffle/run areas serve as grade control for the stream.

On average, cross sections from the Newcut Road Neighborhood area experienced channel aggradation corresponding to the most active years of construction (2004, 2005 and 2006), and then channel degradation and some widening in 2007 as this area of the Newcut Road Neighborhood neared final elevations and stabilization (Fig. 4.10). On the other hand, the Little Bennett Regional Park (Fig. 4.11) and Germantown (Fig. 4.12) cross sections show little yearly change. Changes in cross section are most obvious in the lower half of each profile, corresponding to levels that frequent storms would impact. Surface hydrology analysis has shown that the amounts of annual runoff infiltrating the ground has decreased, annual stream runoff has increased and that the Newcut Road Neighborhood stream had a more rapid response to storms. These changes to surface hydrology would cause the stream to move more sands and gravels in the channel and aggrade (Paul and Meyer 2001). The S&EC BMPs on the development sites were functioning as designed and maintained. However, even the best maintained and functioning S&EC BMP are not 100% effective in removing fine clays and silts.

Evaluation of sinuosity over time documents a difference between the test and control stations. Sinuosity is the ratio between the length of the stream and the corresponding length of the stream valley. A ratio of 1:1 would indicate a very straight and often channelized stream. Sinuosity indices for the Newcut Road tributary reveal the stream has straightened over time (ratios went from 1.4 to 1.0 in just four years (Table 4.2). The sinuosity of the Sopers Branch channel has remained fairly similar, while the sinuosity of the Germantown control stream has straightened somewhat, but not nearly as pronounced as the Newcut Neighborhood tributary. This would be consistent with the increased annual runoff of the Newcut Road Neighborhood stream.

Changes in stream morphology would largely be a result of the changes reported on stream hydrology. There are many comparison studies yet to be done between the test and control areas to evaluate the effectiveness of stormwater BMPs. Results presented herein are preliminary as the S&EC control devices have not been converted to SWM structures. However, from the preliminary results, the construction phase of development has impacted the 104 tributary channel morphology due to channel straightening, down-cutting, and enlargement. Final conclusions will be made once the development process has been completed in the test areas and when the S&EC BMPs have been converted to final SWM BMPs.

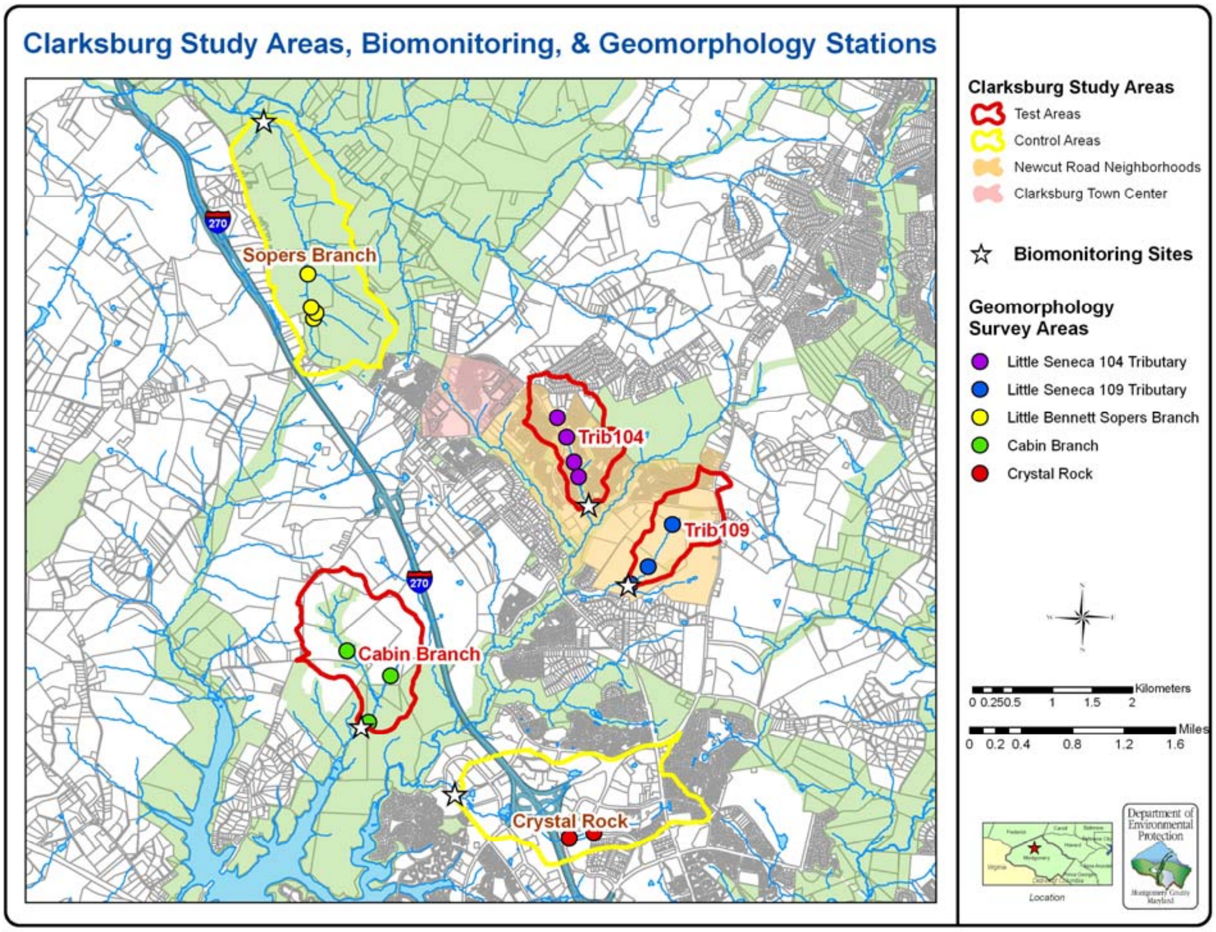
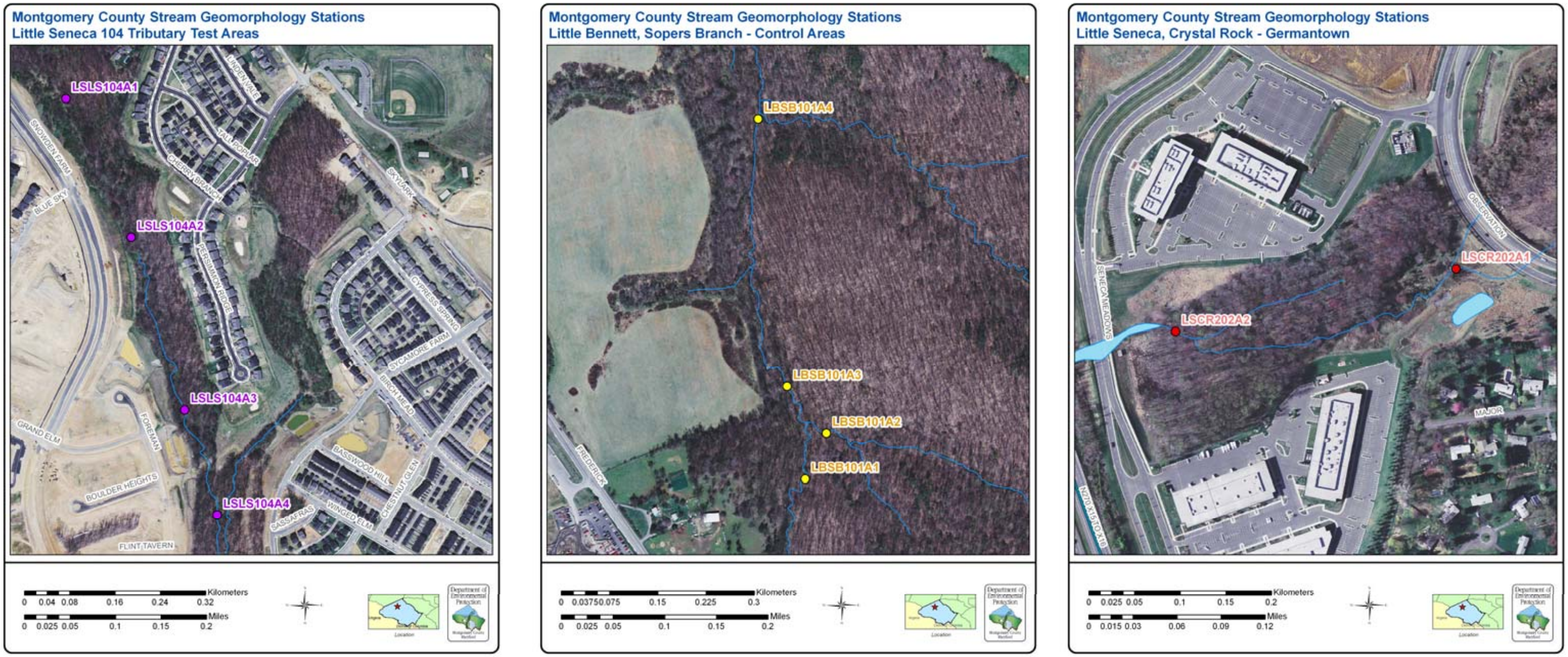
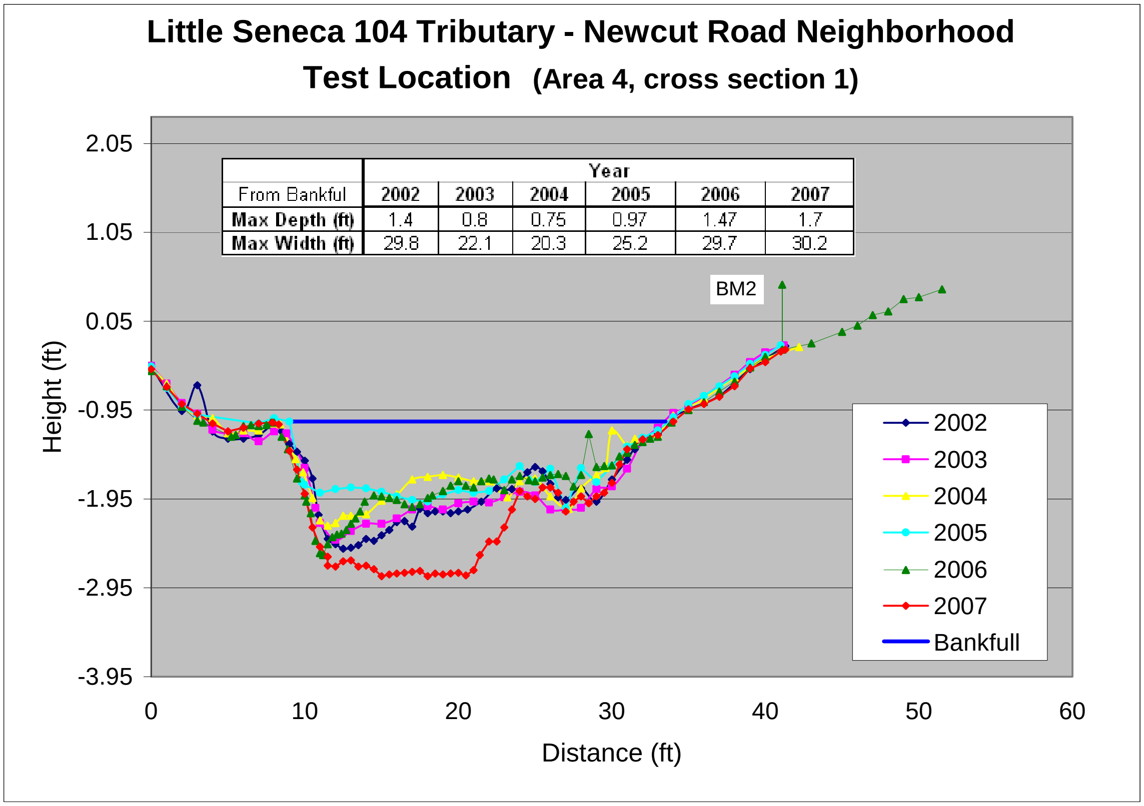


Figure 4.8. Location of the Clarksburg Monitoring Partnership BACI three test areas and two control areas. Also included are biological monitoring stations and geomorphic survey locations.



A **B** **C**

Figure 4.9. Little Seneca 104 tributary (Newcut Road neighborhood) geomorphology survey test areas (A), Little Bennett Creek survey control areas (B), and Germantown negative control survey areas (C).



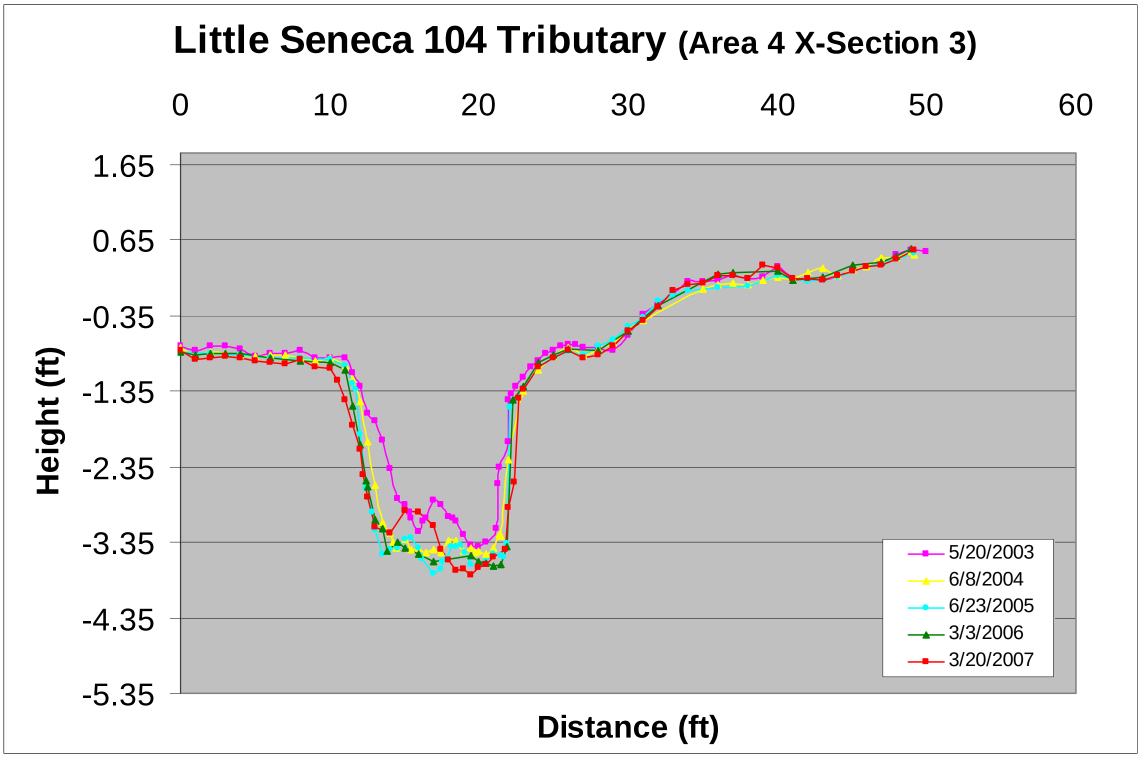
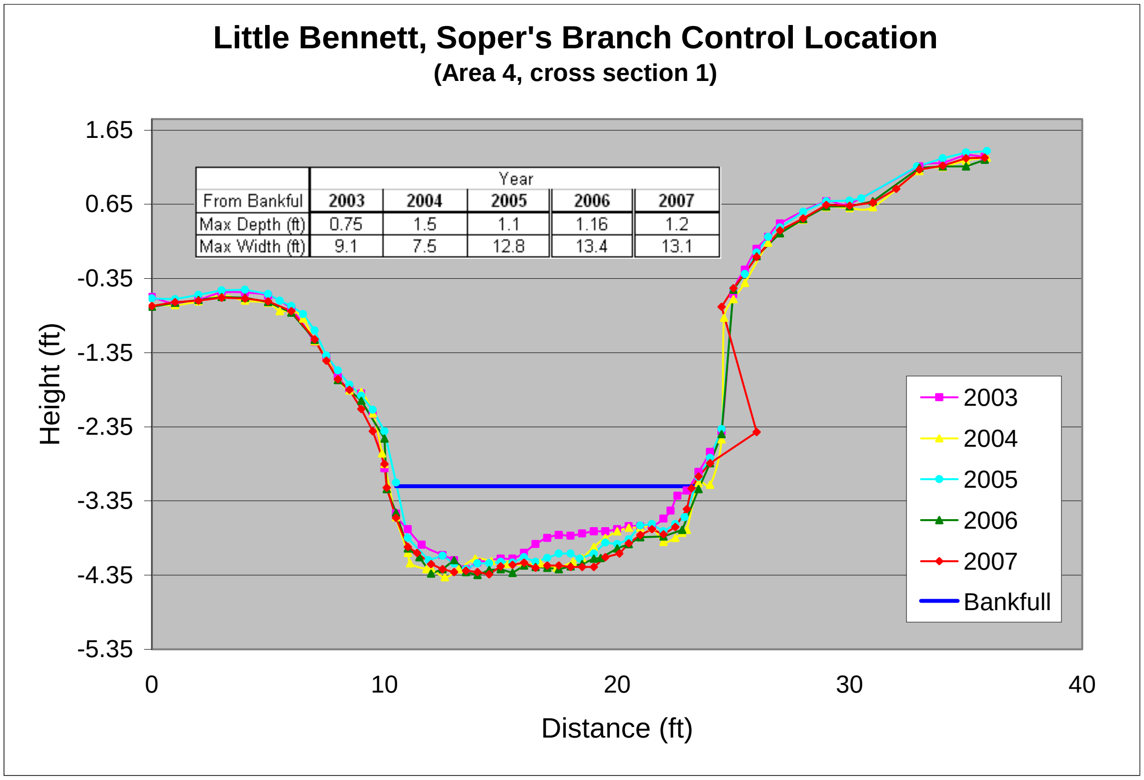


Figure 4.10. Representative cross sections from Newcut Road Neighborhood, Little Seneca 104 Tributary test location, Area 4. Cross sections are both measured in Riffle/run features.



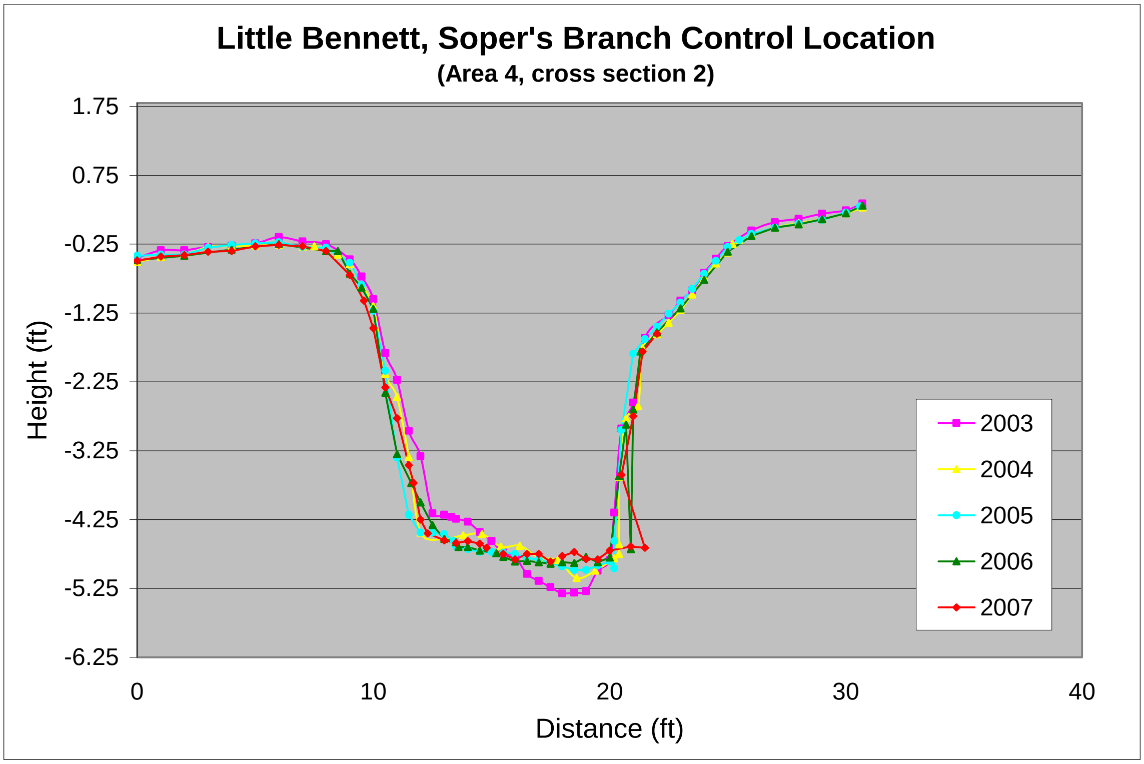


Figure 4.11. Representative cross sections from Little Bennett Creek, Sopers Branch control location, Area 4. Cross sections both measured in Riffle/run features.

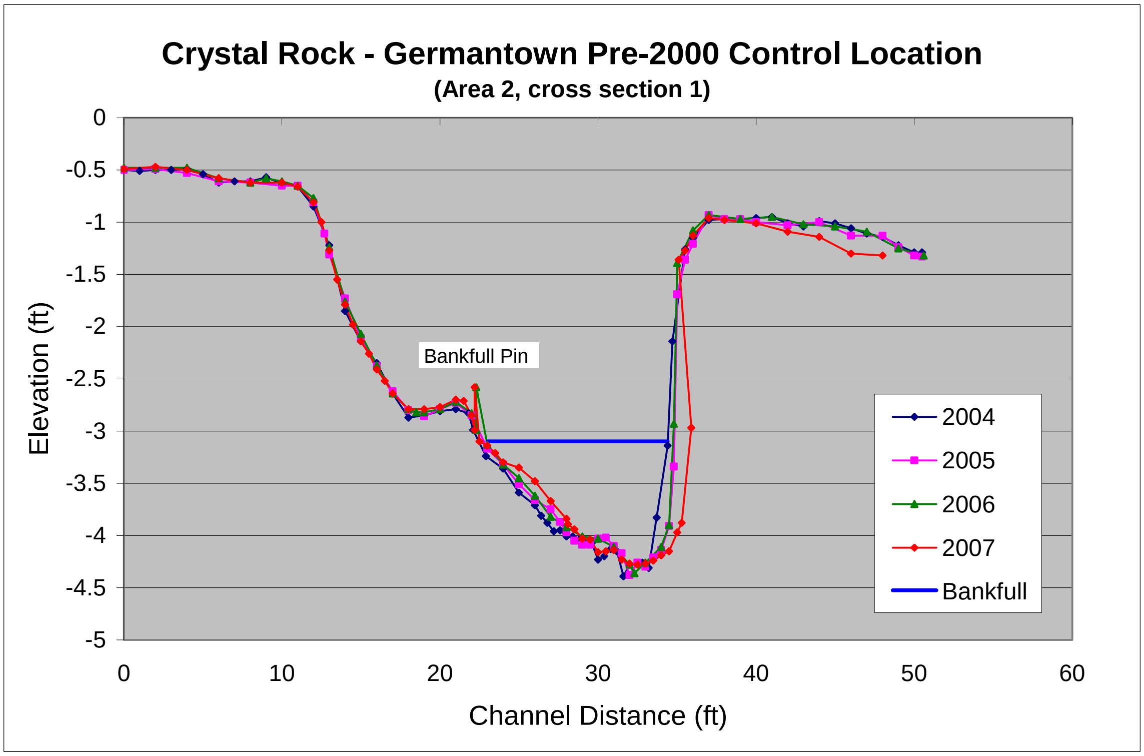


Figure 4.12. Representative cross sections from Germantown (Crystal Rock) pre-2000 control location, Area 2. Cross section 1 measured in a Riffle/run feature.

Table 4.2. Sinuosity indices for Newcut Road Little Seneca 104 tributary test area, Little Bennett Soper's Branch control area, and Germantown Crystal Rock control area. Data is shown for furthest downstream areas within each test and control.

Sinuosity at 104 Tributary Test, Sopers Branch Control, and Crystal Rock Control

	Sinuosity				
Year	'03	'04	'05	'06	07
LSLS104 A4	1.4	1.4	1.3	1.0	1.0
LBSB201 A4	1.1	1.1	1.0	1.2	1.2
LSCR201 A2	-	1.4	0.8	1.3	1.2

4.4 Changes in Physical Chemistry

4.4.1 Water temperature (Clarksburg and Paint Branch)

Stream water temperature plays an important role in maintaining the health of the stream's biological community. Previous SPA Annual Reports (2005; 2006) identified the two principal stressors that influence stream temperature as 1) natural variations in air/stream interactions, and 2) thermal impacts due to runoff from impervious surfaces and BMP storage facilities. SPA BMP design features are selected to avoid thermal impacts to receiving streams. Water temperature is being monitored in all SPAs during the pre, during, and post construction phases. The data will be analyzed to determine how effective the SWM BMPs are in minimizing impacts to stream water temperatures as a result of land use changes at different levels of imperviousness.

4.5 Water Quality

DEP measures *in situ* (on-site) water chemistry data whenever a crew conducts biological monitoring at a stream. This in-situ data is limited in its use and application because it provides information on the stream only at the time and location of the sample. Continuous sampling provides for the full range of water chemistry changes over time, but the cost and resources needed to provide, maintain, and calibrate a water chemistry recording meter at all the SPA stations is prohibitive. In-situ water chemistry samples are collected for dissolved oxygen, percent dissolved oxygen saturation, pH, and conductivity. The data collected from the Clarksburg control and test stations was graphed and examined to see if there was a noticeable water chemistry difference over time between the two groups of stations. No noticeable difference was observed between the stations. All graphs are available in the Technical Appendix to this report.

4.6 Habitat

A Rapid Habitat Assessment (RHAB) is used during spring and summer sampling at all stream stations monitored in the county. An individual score is selected within categories of *optimal*, *sub-optimal*, *marginal*, and *poor* and a total score (out of 200) is generated for the station. Results are provided in the Technical Appendix.

There is no clear trend in the three SPAs and no substantial difference was found between the test and control areas. In a study of the effects of construction and stormwater management in the Peter Pan watershed in Frederick County (2007), embeddedness and *epifaunal substrate* quality have been showing a slow decline over time. It is possible that impacts at individual sites can be confounded when combined with others.

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5. Biological Integrity

Stream biological communities are primarily affected by stream habitat availability, which is heavily influenced by changes in stream geomorphology and hydrology.

5.1 Biological Stream Monitoring

Biological monitoring evaluates stream condition and records changes in the stream community over time. The monitoring of fish and benthic macroinvertebrate communities is used nationally and regionally to measure the overall health of a stream. Both biological communities provide information on short-term and long-term impacts. Fish and benthic macroinvertebrates populations display a range of *tolerances* within each community and these populations will survive or die in relation to the degree of cumulative impacts in the stream. For examples of tolerance values and *functional feeding groups*, see the Technical Appendix. Adults may survive intitially, but the cumulative impacts can affect reproductive success to the point where the population no longer produces enough viable offspring to maintain the population. DEP developed an index to compare the stream community (fish and benthic macroinvertebrates) to those found in the least impaired streams located in the County and surrounding areas. DEP began stream monitoring within three SPAs, Clarksburg, Piney Branch, and Upper Paint Branch in 1995 and within the newly-designated Upper Rock Creek SPA in 2004. Stream monitoring includes biological sampling of benthic macroinvertebrate (bottom-dwelling aquatic insects and worms), fish communities, as well as amphibian & reptile populations. Stream monitoring also includes habitat assessment, stream channel measurements, and water quality readings (dissolved oxygen, temperature, pH, and conductivity), which were discussed in Section 4. For a table of available stream monitoring data and a discussion of stream monitoring protocols, see the Technical Appendix.

In the SPAs, the County attempts to minimize the cumulative effects caused by development and land use change. Biological monitoring is a cost-effective tool to assess the degree of cumulative impacts in streams and rivers including altered stream hydrology, channel erosion, and sedimentation. These factors are often observed when a watershed undergoes extensive land use change. Generally, individual stream chemistry and physical parameter measurements do not identify the major factors impacting resource conditions in county streams. Careful monitoring and comparison of streams not impacted by development and streams with ongoing development can isolate impacts caused by natural conditions (drought, flooding) from those caused by development (mass grading, sedimentation, increased impervious surface).

Aquatic benthic macroinvertebrates live in the bottom parts of our waters. Benthic macroinvertebrates make good indicators of watershed health because they (U.S. EPA 2007a):

- Live in the water for all or most of their life, staying in habitat areas necessary for their survival,

- Rapidly respond to short term impacts as individual taxa differ in their tolerance to amount and types of pollution,
- Have limited mobility, and
- Respond to the cumulative impacts from all of the chemical, physical, and biological stressors to the receiving stream in predictable and characteristic patterns.

Specific attributes of fish that make them desirable components of biological assessments and monitoring programs (U.S. EPA 2007b):

- Fish have large ranges and are less affected by natural microhabitat differences than smaller organisms. This makes fish extremely useful for assessing regional conditions.
- Most fish species have long life spans (2 to 10 years or more) and can reflect both long-term and current water resource quality.
- Fish continually inhabit the receiving water and integrate the chemical, physical, and biological histories of the waters.
- Fish represent a broad spectrum of community tolerances from very sensitive to highly tolerant and respond to chemical, physical, and biological degradation in characteristic response patterns.

Benthic macroinvertebrates tend to be stronger indicators of stream health in headwater areas with short term disturbance, where impacts to the stream are much more concentrated in time and space. Fish, with their longer life-spans and increased mobility, give stream health information on a larger scale both spatially and temporally. Combined in an average, the benthic and fish *metrics* give a much more inclusive, holistic evaluation of a stream's overall biological condtion.

Measures (metrics) of each biological community are assembled to form an *Index of Biological Integrity (IBI).* The metrics used for benthic macroinvertebrate and fish IBIs can be found in the Technical Appendix. Metrics are selected that respond in a predictable way to increasing degrees of cumulative impacts. Metrics are scored in comparison to the least impacted streams in the region. The final IBI creates an index that compares any stream against conditions found in these least impacted streams. Streams are rated as *excellent, good, fair,* or *poor*.

The U.S. EPA (1990) recommends using two or more indicator groups to provide a more realistic evaluation of system *biological integrity*. A Stream Salamander IBI has been developed for Maryland and has undergone several validations (Southerland et al. 2004; Southerland and Franks 2008). Stream salamanders spend their entire lives instream or closely associated with the stream channel. Because of their longevity, small home ranges, relatively stable populations, abundance and ubiquity, salamanders have been identified as promising indicators of water quality. Furthermore, they replace fish as top predators in small, headwater streams (Jung et al. 2004; Southerland and Stranko 2006). DEP is examining the use of stream salamanders as indicators of water quality in small streams (less than 300 acres drainage area) to complement the benthic macroinvertebrate IBI scoring results.

Presently, there are 57 stream monitoring stations throughout the four SPAs: 27 in Clarksburg; 14 in Upper Paint Branch; 10 in Piney Branch and six in the Upper Rock Creek SPA. Because of staff constraints, not all 57 stations are able to be monitored each year. For maps showing the location of all biological monitoring stations in the four SPAs, see the Technical Appendix.

5.2 Stream Condition Comparison

This section compares the overall IBI of three SPAs from the onset of SPA designation to the present. The Upper Rock Creek SPA is not included in this section because development has not started in the SPA during the reporting period. According to Morgan and Cushman (2005), small (1st to 3rd order) headwater streams are particularly at risk from development impacts. Altered flow regimes from urbanization can affect fish assemblage structure and biodiversity by re-shaping the streams physical habitat on too short a time scale (years to decades) to allow populations to adjust. Miltner et al. (2003) suggested that poorly regulated construction practices constitute the first step toward declining stream health in suburbanizing landscapes.

Within each SPA, stream conditions (the average of the fish and benthic IBI scores) changed over time. In Clarksburg, the stream conditions were predominantly *good* to *excellent* before development occurred (Fig. 5.1). Currently, stream conditions have

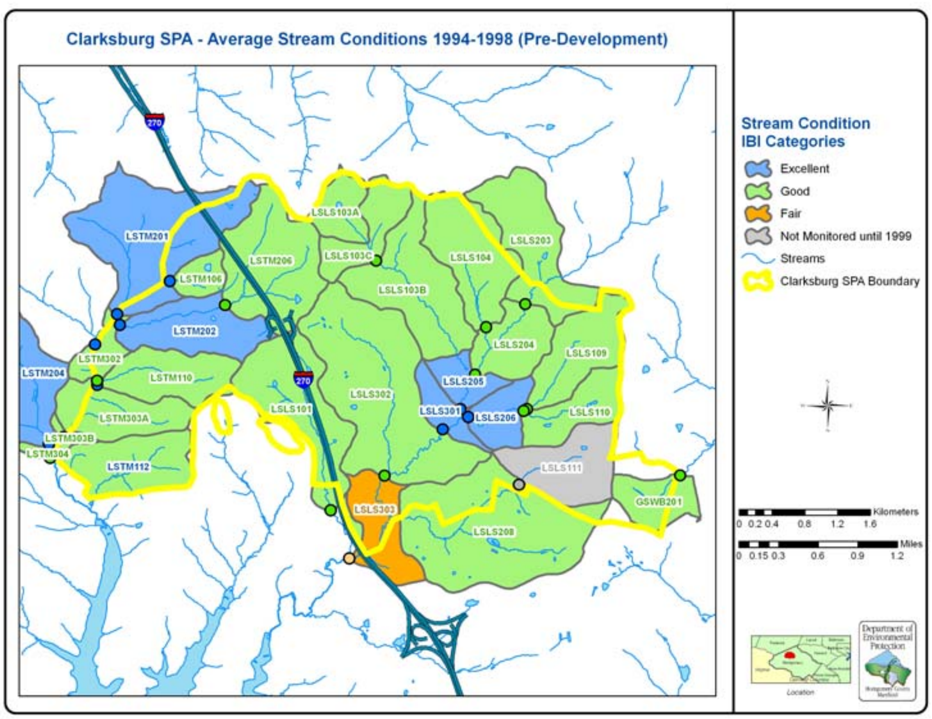

Figure 5.1. Pre-development (1994-1998)) stream conditions (average of fish and benthic % IBI scores) in the Clarksburg SPA.

dropped into the *fair* category primarily in the Clarksburg Town Center and Newcut Road development areas (Fig. 5.2). The headwater area of Ten Mile Creek also declined to *fair* during this period. This area partially receives runoff from the Clarksburg Detention Center as well as runoff from areas upstream of I-270. An investigation was made into possible reasons for the decline, (as reported in the 2006 SPA Annual Report), and high conductivity readings were found throughout the drainage area to the station. No specific cause for the high conductivity readings could be identified, but the fragility of the Ten Mile Creek to impacts was undeniable.

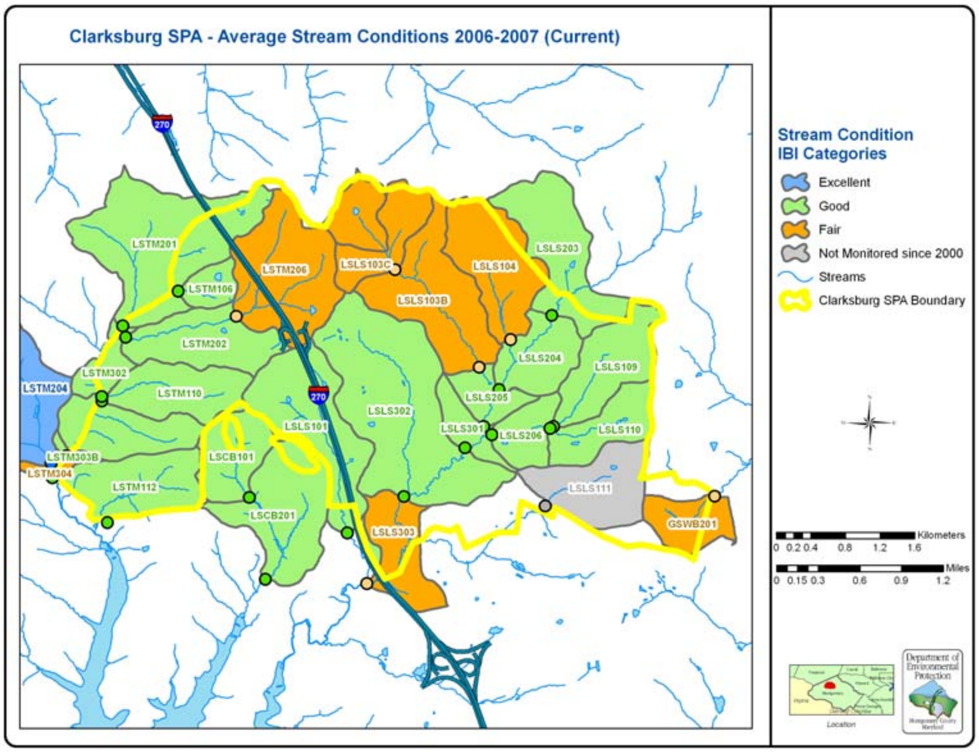

Figure 5.2. Current (2006 & 2007) stream conditions (average of fish and benthic % IBI scores) in the Clarksburg SPA.

Paint Branch stream conditions were also predominantly *good* to *excellent* before the development period (Fig. 5.3). Current stream conditions in the Right Fork tributaries have dropped only slightly to a *good* rating, while the Left Fork tributary has gone from *good* to *fair* in the headwater areas where development may have had a greater impact (Fig. 5.4).

For Piney Branch, new development and lack of an impervious cap in the upper parts of the SPA may have caused the stream conditions to drop from predominantly *fair* (Fig. 5.5*)* to mostly *poor* (Fig. 5.6).

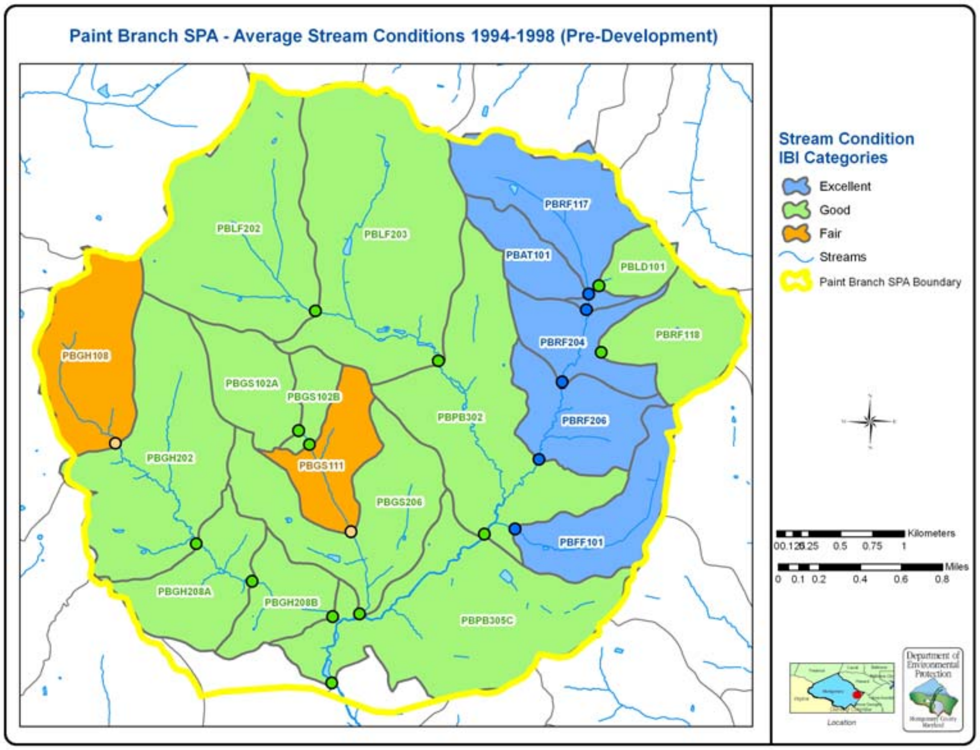

Figure 5.3. Pre-development (1994-1998) stream conditions (average of fish and benthic % IBI scores) in the Paint Branch SPA.

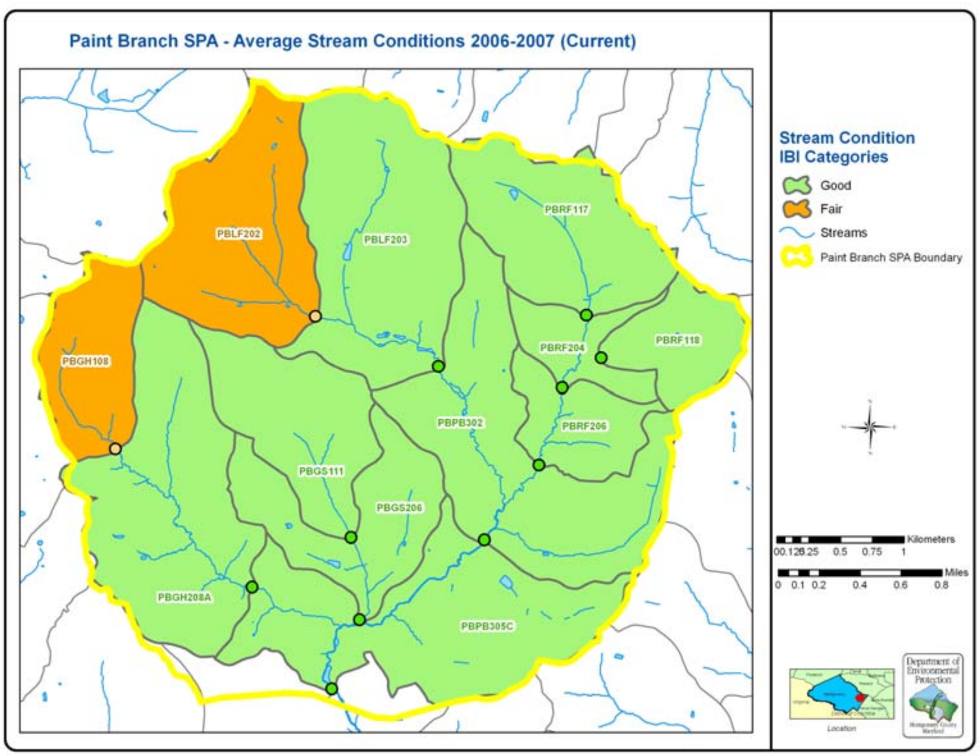

Figure 5.4. Current (2006 & 2007) stream conditions (average of fish and benthic % IBI scores) in the Paint Branch SPA. Stations PBGS102A, PBGS102B, PBGH202, PBAT101, and PBFF101 were not monitored in recent years due to monitoring priorities in other SPAs, so their drainage areas were absorbed by downstream active stations.

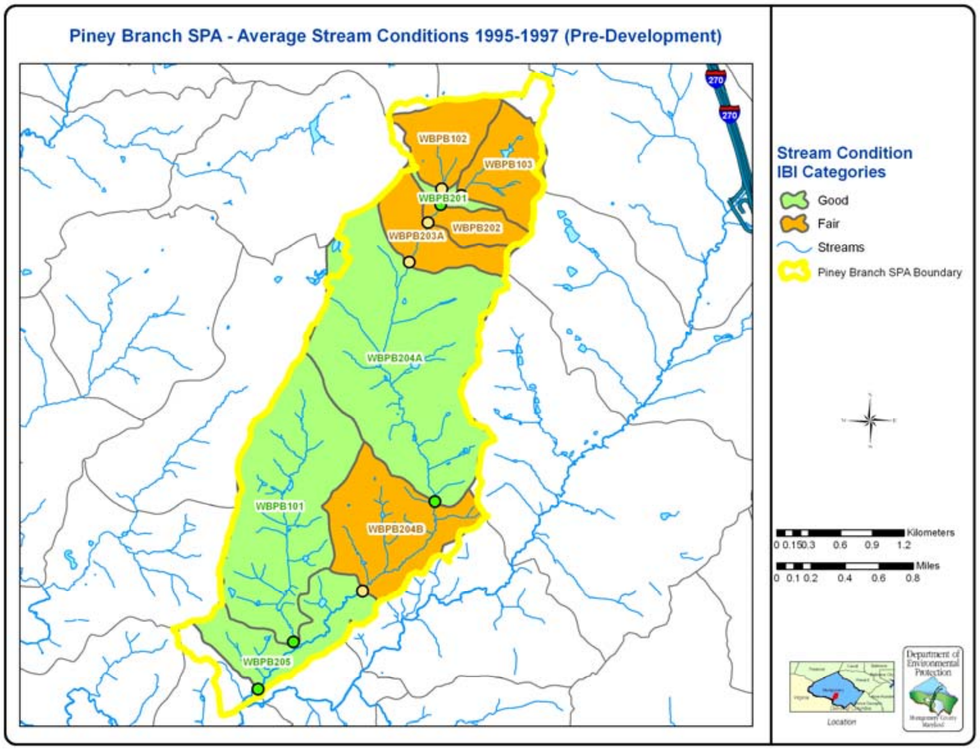

Figure 5.5. Pre-development (1995-1997) stream conditions (average of fish and benthic % IBI scores) in the Piney Branch SPA.

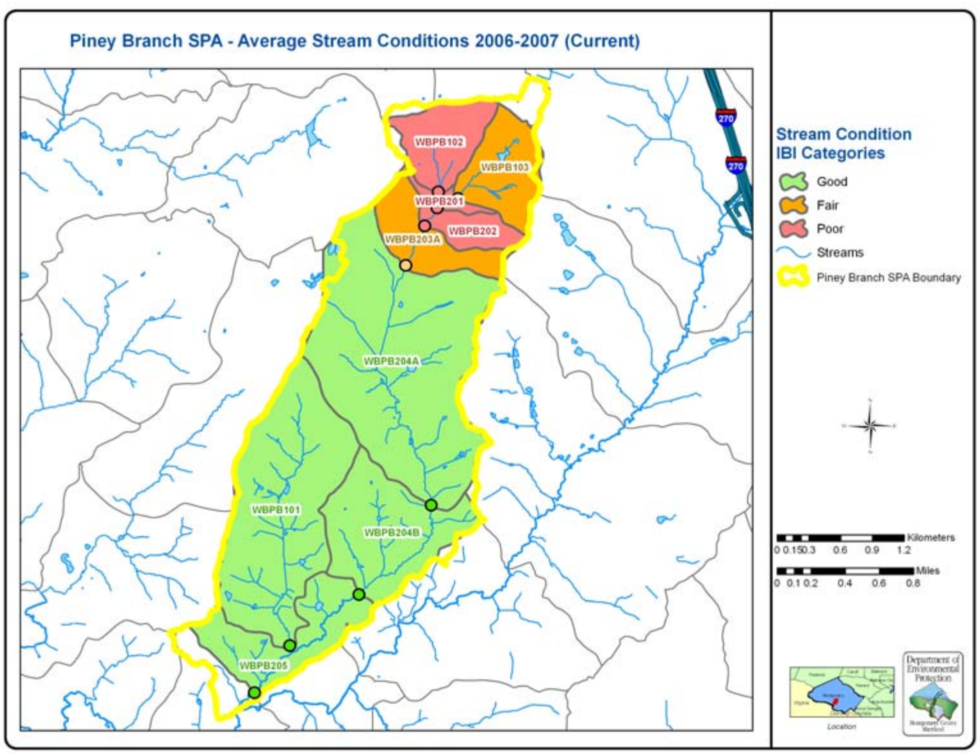

Figure 5.6. Current (2006 & 2007) stream conditions (average of fish and benthic % IBI scores) in the Piney Branch SPA.

5.3 Benthic Macroinvertebrate IBI Score Comparison

In order to evaluate how effective the methods, facilities, and practices utilized through the construction phase of development are in protecting the water quality of Special Protection Area streams, DEP compared the changes in the benthic macroinvertebrate index ratings of a control set of monitoring stations to those of a test set of monitoring stations before and during the development period (Table 5.1). The control set of stations had no *new* development (i.e. no new areas of disturbed land) occur in their drainage areas; the test set of stations had the majority of their drainage areas *newly* disturbed through the development process. Both sets of stations were identified and analyzed from the same Special Protection Area watersheds. Monitoring was done at the same time of year using the same methods. Stations are close to each other so that the same naturally occurring events would affect all stations. Benthic samples were collected in the spring of the year, so summer/fall drought impacts would be reflected in the following year's results.

The rationale for concentrating on benthic scores is that most of the stations used for this comparison are small headwater streams, where benthic macroinvertebrates are expected to be a more responsive indicator group. Fish that live in the smaller headwater streams tend to be those that can survive in the available habitat and are called "*pioneer*" fish. Pioneer fish species are able to survive a wider range of stressors than the benthic macroinvertebrate community and respond differently. Generally, the fish community

Table 5.1. Control and Test Stations

SPA Area	Control Station Watersheds	Control Stations	Test Station Watersheds	Test Stations
Clarksburg	Ten Mile Creek, Little Seneca Creek	8	Little Seneca Creek (primarily Newcut Road & Town Center Neighborhoods)	9
Piney Branch	Western Tributary of Piney Branch	1	Stations above Glen Hill Road	5
Upper Paint Branch	Good Hope, Gum Springs	4	Right Fork	6

will persist as long as their habitat and food is present. As the abundance of food sources declines for the fish that eat primarily insects and other invertebrates, it would be expected that the fish community scores would decline as well. This may not be apparent until some years after the development process has been completed. Finally, in Ten Mile Creek, a barrier to fish recolonization is present downstream by the Little Seneca Lake. For an analysis of the fish community trends in the three SPAs (fish are not monitored in the Rock Creek SPA), see the Technical Appendix.

5.3.1 Clarksburg

Land use in the control area is predominately rural agricultural and topography has not changed. Many of the control stations are from Ten Mile Creek. The test set of stations had the majority of their drainage areas disturbed through the development process. Most of the test stations are in the Town Center and Newcut Road Neighborhoods.

Median benthic index scores for both the control and test stations were very similar from 1995 to 2002 (Fig. 5.3). Median scores were in the *good* to *excellent* range during this period. Construction began in the Clarksburg test areas in 2002; a record drought also occurred throughout the County during 2002. The median scores diverged in 2003. The stations under construction dropped to a *fair* condition, while the stations without the development dropped but remained in the *good* benthic IBI category. From 2003 onwards, the streams within the test areas showed no signs of recovery and were nearing the *poor* benthic IBI category. Streams in the control areas improved and recovered to their previous rating between *good* and *excellent*.

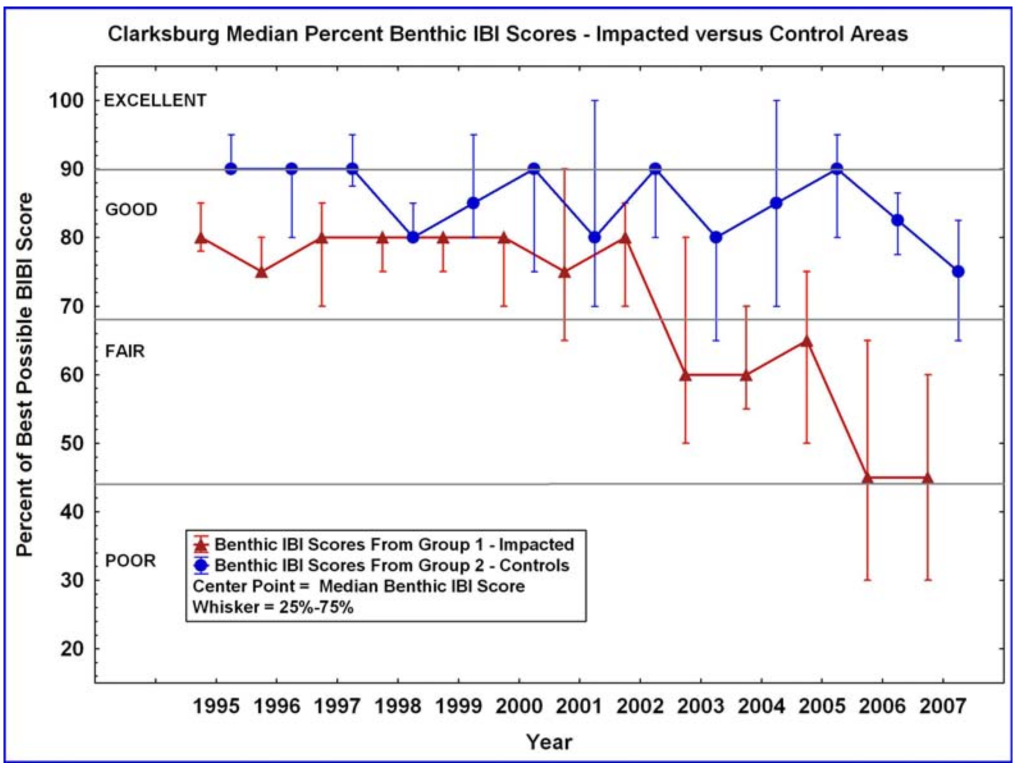

Figure 5.3. Median Benthic IBI Scores for Clarksburg Control and Test Areas.

The lines, or "whiskers" on the graph, which extend above and below the median points indicate the range of scores for each group of stations during each monitoring year (25th and 75th percentiles). As the median score of the test and control stations diverge, the range of scores recorded for the two groups also diverge, until they no longer overlap in 2005. The scores of the undeveloped control and developed test stations are significantly different from 2005 to present. Based on the available data, the development process thus far has had a measurable impact on stream conditions in the Little Seneca Creek watershed.

5.3.2 Ten Mile Creek

As stated in section 1.2.2, the Ten Mile Creek watershed has been identified as an environmentally sensitive area of county-wide significance (M-NCPPC 1994). Prior SPA Reports have provided information on the year-to-year stream conditions for Ten Mile Creek. The monitoring data supports the designation of Ten Mile Creek as an "extremely environmentally sensitive area of county-wide significance" (M-NCPPC 1994). Base-flows continue to be low in the summer months and the creek is susceptible to low flows from lack of rain. However, even in the driest years, tributaries have continued to flow and provide cool clean water as a refuge for the stream community. The watershed remains a very fragile system dependent on the contribution of cool, clean water from its tributaries to maintain healthy stream conditions.

In 2007, fisheries biologists discovered three adult brown trout some distance above the West Old Baltimore Road ford. The trout represented different age classes and did not appear to be hatchery raised. The trout were weighed, measured, and returned to the creek. Fisheries biologists returned and conducted a wider survey of the creek but did not find additional trout. It is uncertain if the three adults found are natural occurring to Ten Mile Creek or not.

5.3.3 Piney Branch SPA

Results are very similar to the Clarksburg SPA for the control and test stations in the Piney Branch SPA (Fig. 5.4). Changes in median stream conditions among test and control stations followed each other closely until 1998. Much of the new SPA development in the upper Piney Branch has occurred since 1998. From 1998, benthic IBI scores in the control station stayed in the *good* range. Benthic conditions in the test stations declined to *poor* in 1999 and stayed in the *poor* range since 2003. Again, naturally occurring events such as drought and rainfall affected all stations at the same time. The test stations had the majority of their drainage areas in the development process during this time.

5.3.4 Upper Paint Branch SPA

The time series between control and test stations are quite different for the Upper Paint Branch SPA stations (Fig. 5.5). Yearly changes in both the test and control stations show similar benthic community health patterns. There is not much difference between the test and control stations that can be attributed to the development processes occurring in the test stations drainage areas as the ranges of both the test and control stations fully overlap.

The 2002 drought had a major impact to the Upper Paint Branch as shown in the benthic scores beginning in 2003. Since benthic macroinvertebrate monitoring is done in the

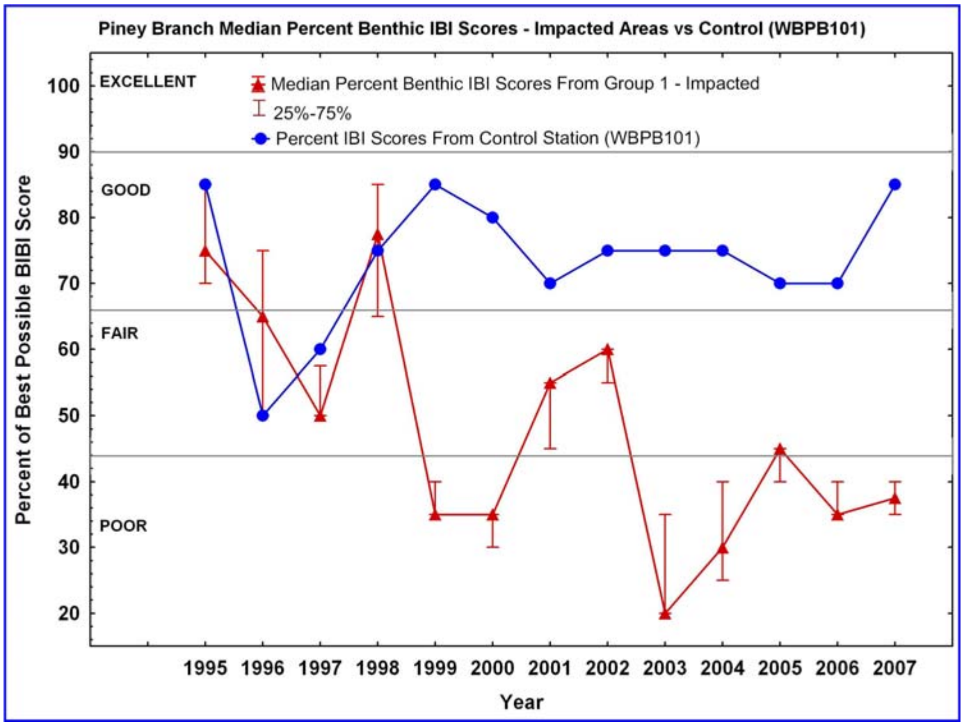

Figure 5.4. Median benthic macroinvertebrate IBI scores for Piney Branch control and test areas.

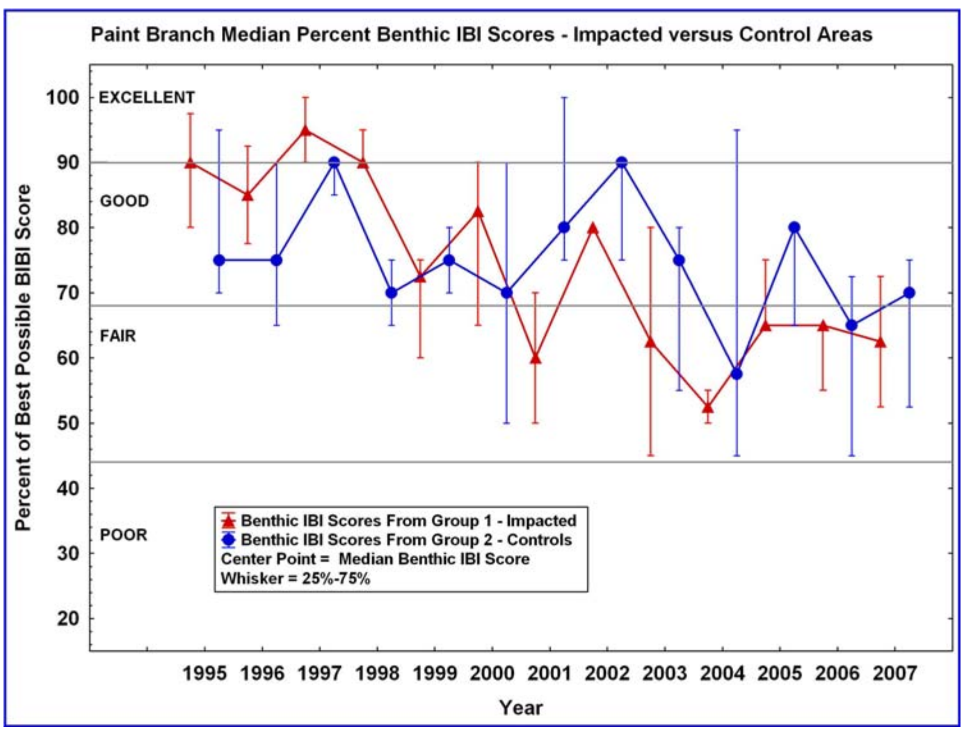

Figure 5.5. Median benthic IBI scores for Upper Paint Branch control and test areas.

spring and drought impacts are typically observed in the summer, changes in the benthic macroinvertebrates communities will tend to be found during the following spring. The Right Fork of the Upper Paint Branch is likely to recover to near pre-construction level stream conditions even though measurable impacts are present in the test stations because the benthic community structure remains intact and basically unchanged even after the majority of the development in the Right Fork subwatershed has been completed and BMPs converted from S&EC to SWM facilities. This recovery will be monitored after the new SWM controls are functioning as designed.

According to monitoring data going back to 1994, brown trout populations have persisted in the Upper Paint Branch SPA. See the Technical Appendix for more information.

5.3.5 Upper Rock Creek SPA

Benthic IBI scores in the small headwater streams monitored for the Upper Rock Creek SPA have consistently been *good* since 2004 (Fig. 5.6). No large areas have been opened for development as of the date of this report. Stations are not separated into control and test areas at this time.

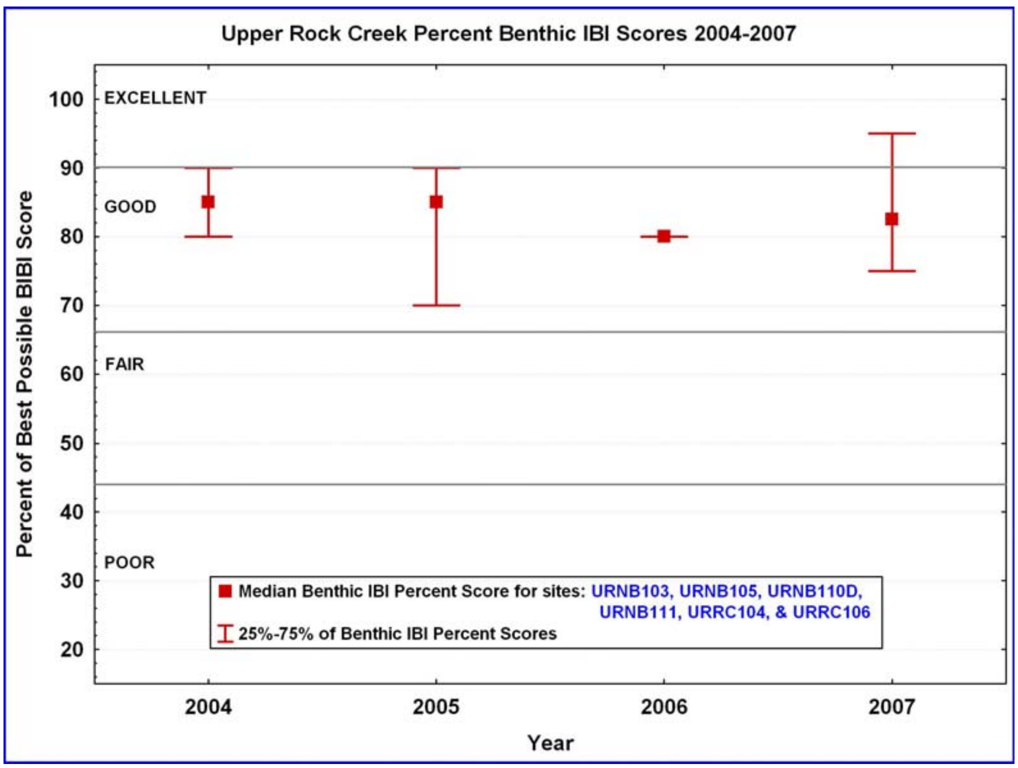

Figure 5.6. Median benthic IBI scores for Upper Rock Creek control and test areas.

5.4 Changes in Benthic Macroinvertebrate Community Structure and Function

5.4.1 Introduction

Previous SPA reports have discussed the expectation that the stream conditions in the watershed will recover to pre-development levels once the development process has been completed. Predicting how much potential there is for recovery requires understanding the changes within the biological community that cause the changes to the ratings. An examination of the metrics (measurements) of the biological community is done for this task. See the Technical Appendix for a complete list of metrics that comprise both the fish and benthic IBIs.

This section of the report examines changes over time using metrics of community structure (dominant taxa) and community function (functional feeding groups) for the benthic macroinvertebrate community. Dominant taxa are those organisms that make up the majority of the sampled community. Functional feeding groups are designations that characterize how organisms in the community obtain food. For more discussion on functional feeding groups and dominant taxa, see the Technical Appendix.

One of the uses of the IBI is the ability to detect differences in individual metrics and determine impacts using additional information such as habitat, chemistry, and land use information (Simon and Lyons 1995). Additionally, examining the composition and function of the community supplements the score and provides insight into the direct effects of environmental change and decline (Pederson & Perkins 1986).

5.4.2 Changes in Community Structure and Function

A shift in functional feeding group composition is noted in the test areas of all SPAs and appears to have coincided with development activities (see Technical Appendix for more in-depth analysis of these shifts). The shift from sensitive and specialized feeders, such as *shredders*, to generalist and more tolerant groups, such as *collectors* and *filterers*, are characteristic of disturbed streams that have been altered by urbanization processes. Similarly, a dominance of pollution-tolerant and less sensitive Chironimidae seen in the SPAs is frequently observed at disturbed sites like those in altered landscapes (Pedersen and Perkins 1986; Jones and Clark 1987; Moore and Palmer 2005; Diana et al. 2006).

This suggests that habitat as well as food quality and availability changed in these areas as a result of construction activities, thereby negatively impacting the benthic fauna. Good quality habitat, (such as stable and vegetated banks, wide, sinuous stream channels with coarse substrates, and ample and diverse cover and substrate), is associated with a diverse biological community. Conversely, unvegetated and eroding banks and deep channels with predominantly fine substrates are associated with poor biology (Pedersen and Perkins 1986; Jones and Clark 1987; Heitke et al. 2006; Moerke and Lamberti 2006).

Changes in community feeding structure and function were most obvious in the Clarksburg and Piney Branch SPAs, particularly with the dominance of more tolerant collectors and Chironimidae. Clarksburg and Piney Branch both underwent high-density, rapid development, but differ in that Piney had previous developments exerting legacy effects (Wang et al. 2006) while recent development in the Clarksburg Newcut Road and Town Center neighborhoods has left a lot of exposed and unconverted land, limiting recovery at this time.

The level of disturbance in each SPA during construction periods was an important influence on benthic community structures and functions. The Paint Branch SPA stream conditions and biological communities in the test areas did not differ considerably from the control areas. It appears that the 10% over existing impervious cap restricting the amount and impacts of development as well as the relatively small window of development from 2003 to 2006 may have limited some impacts to these areas.

5.4.3 Future stream conditions and potential for recovery

The changes to the structure and function of the benthic macroinvertebrate community are reflected in the declining stream condition scores. The frequent, intense, and ongoing disturbances through the construction period, particularly in the Clarksburg Town Center and New Cut Road areas, may have impacted the ability of the benthic communities to recover (Moore and Palmer 2005). If sensitive organisms are no longer present or if the habitat no longer supports these more sensitive taxa, the stream condition may not be able to improve. Disruption to the natural system through the conversion of rural land use to urban land use may prevent a full recovery to pre-construction conditions (Konrad and Booth 2005; Wang et al. 2006). However, some improvement to habitat, and thereby benthic communities, is expected upon conversion to SWM.

Stream communities demonstrate some ability to recover following the flushing of deposited materials (Jones and Clark 1987). Recovery of benthic macroinvertebrates is expected as the pace of new construction slows, and areas are converted to SWM (Miltner et al. 2004). However, the level of recovery and the influence of BMPs is unclear at this time. Some findings indicate that large-scale and long-term disturbances in a watershed limit the recovery of stream communities for many decades (Harding et al. 1998) and that the impacts to the form and function of the aquatic systems occur rapidly and are very difficult to avoid or correct (Booth and Jackson 1997). Although promising, the more stringent stormwater regulations and BMPs such as those utilized by the County have not been in place long enough to test whether they will minimize loss of aquatic life through development and build out. In addition to protecting streams by managing adjacent land use (e.g. leaving riparian zones intact, floodplains under-developed, and adjusting for potential hydrological impacts; described in Miltner et al. (2004)), it may be necessary to preserve entire watersheds, not just fragments or pieces of them (Harding et al. 1998).

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6. Summary/ Results

The results of the early monitoring indicate that the S&EC and SWM structures are generally performing as expected. However, the biological monitoring in those watersheds shows that the cumulative effects of development are negatively impacting water quality. Because there is ongoing construction in all of the SPA watersheds, it is not possible to segregate the effects of ongoing construction from the post construction monitoring results.

6.1 Land Development

The development process permanently changes the character of the landscape. These changes are cumulative and influence the receiving streams in ways that must be assessed using an indicator of cumulative impacts such as biological monitoring. LiDAR imagery has followed the development of the Newcut Road neighborhood through 2007. Final grades are seen throughout the site (Figs. 4.1, 4.2, 4.3, and 4.4) as the rolling topography was cut, graded, smoothed, leveled, and compacted. The overall topography, natural drainage patterns, and natural infiltration has been altered due to the cut and fill requirements necessary to meet the density requirements of these neighborhoods and the diversion of most of the surface runoff into stormwater inlets and drains. These changes to the landscape alter hydrology and can permanently affect water quality.

6.2 Imperviousness

The Impervious Cover Model has shown that most stream quality indicators will decline when watershed imperviousness exceeds 10%, with severe impairment occurring when imperviousness exceeds 25% (CWP 2003). A preliminary regression model developed by DEP, and based solely on available county stream quality and watershed impervious area data, also predicts that average aquatic insect IBIs could decline to the *fair* category when imperviousness exceeds 8%. When imperviousness exceeds 21%, the model predicts that average aquatic insect IBIs may shift to the *poor* category.

The new SPA SWM BMPs attempt to minimize the impacts of the newly built impervious areas by providing opportunities for stormwater to infiltrate into the ground, and by providing volume control so that the volume of stormwater discharged from the SWM BMPs is reduced.

Few studies have actually followed a small watershed from pre-construction through to the build-out of projects to evaluate the cumulative effects of various combinations of SWM controls, supporting stream buffers, trees, and other stormwater pollutant controls in mitigating watershed development impacts. This is the real value of the Clarksburg SPA monitoring program. The Little Seneca watershed was primarily undeveloped prior to development, allowing for a comprehensive before – after evaluation. As the S&EC BMPs are converted to SWM BMPs in the Special Protection Areas within Clarksburg and the other SPAs, DEP will be able to better quantify how redundant and modern SWM BMPs can help to mitigate the effects of imperviousness on the health of the receiving streams. Thus far, results show that BMPs are performing as expected. However, the efficiency of the BMPs is not correlating to the health of the stream based on its biological health. There is insufficient data at this point in the development process to evaluate if the watershed will recover from the negative effects documented during construction.

6.3 Stream Hydrology

In 2004, the USGS, U.S. EPA, and Montgomery County DEP cooperatively established five stream gages in the Clarksburg SPA as part of the Integrated Clarksburg Monitoring Partnership. Two rain gages were also established in the study area to record localized storm events (Fig. 1.3).

The purpose of the five stream gages is to document changes in stream hydrology as a result of the land use changes and urbanization that are ongoing in Clarksburg. Two of the gages serve as control gages (one in a substantially undeveloped drainage and one in a developed area with SWM BMPs predominately designed from the pre-2000 MDE Stormwater Design manual). Three of the gages are downstream of areas that have or will have significant land use change and urbanization – two in the Newcut Road Neighborhood and one in the Cabin Branch Neighborhood. When development is completed and the SWM BMPs have been converted from S&EC BMPs, changes in storm flows, base flow, and peak discharges can be analyzed and presented. A period of five years after SWM conversion is needed to allow for a sufficient expression of inter-annual variability to occur (dry years, wet years, and normal rainfall years). At this point in the development process, on average, the Newcut Road Neighborhood tributary has measurable differences in stream hydrology from the control gages.

6.4 Stream Morphology

Stream morphology monitoring has been focused in the Clarksburg Master Plan SPA. Newcut Road cross sections experienced a sediment increase in 2003 and 2004 corresponding to the most active years of construction, and channel downcutting and widening in 2007 as the Clarksburg neighborhood neared final impervious levels. The Little Bennett Regional Park and Germantown cross sections show little yearly change compared to the Newcut Road cross-sectional areas. Evaluation of sinuosity over time also shows a visible difference between the test and control stations. These changes in stream morphology are largely a result of the changes reported on stream hydrology.

6.5 Water Chemistry

No clear trends were observed as a result of in-situ monitoring of physical and chemical parameters in the SPAs. Water temperatures were not observed to be adversely impacted to date.

6.6 BMP Efficiency

6.6.1 Sediment and Erosion Control

As indicated in Figure 3.5, monitoring results continue to show S&EC structures receiving dirty, sediment-laden water (likely to occur during the early development periods involving cutting, filling, and grading) are generally effective. Grab sample results show a general decrease in sediment concentrations leaving properly installed and regularly maintained S&EC basins and traps from that entering the basin or trap. All structures sampled showed a range of efficiency in removing suspended sediment such that water leaving the structure was cleaner than water entering the structure.

At concentrations below 100 mg/L, the results are much more variable. In some cases, dirtier water was leaving the S&EC structure than was entering. The higher outfall concentrations could be from the re-suspending of fine clays and silts already in the control structure basin. The County is now evaluating the conversion of S&EC structures to stormwater structures once the majority of the site is built out and stable to prevent previously collected sediment from leaving the site.

6.6.2 Stormwater Management

Most of the data on post-construction conditions collected by DEP up to this time measures BMP effectiveness based on changes to the stream habitat and physical quality such as stream temperature and groundwater levels. The data shows that in general the BMPs are effective at limiting sediment loads, temperature fluctuations, and changes in ground water levels.

Starting in 2001, data has been obtained on the efficiency of individual SWM structures. Data from three SWM BMP structures are presented at this time. The data shows that the three stormwater structures are performing as expected.

6.7 Biological Integrity

For the Clarksburg Town Center and Newcut Road areas, the median benthic IBI scores of a group of stations with undeveloped drainage areas (control group) and a group of stations with developing drainage areas (test group) diverged in 2003. The stations under construction dropped to a *fair* condition while the stations without the development dropped but remained in the *good* stream condition category. From 2003 onwards, the streams with developing drainage areas did not recover and dropped further in category almost into the *poor* stream condition. Streams in the areas without development improve and recover after the 2002 drought to their previous rating of *good* to *excellent,* and then drop slightly into the *good* stream condition category. The development process had a measurable cumulative impact on the stream conditions in the Little Seneca Creek stations including the Town Center and Newcut Road areas.

The trends over the same time period are quite different for the Upper Paint Branch SPA stations. Yearly changes follow each other between the test and control stations. Ranges fully overlap during the time series as well.

The community composition of the Clarksburg test stations (primarily Town Center and Newcut Road neighborhood stream stations) changed drastically during the development process (2003 to 2007). Shredders declined from 47% of the community to 11% of the community. The more general feeding group called collectors increased to over half of the community (53%). The dominant taxon has changed from the pollution intolerant and highly sensitive organism called Amphinemura sp. to the more pollution tolerant and less sensitive Chironimidae family. These changes to the structure and function of the benthic macroinvertebrate commuity are reflected in the declining stream condition scores over the same time period. In order for the stream condition to improve from *poor* and *fair*, the benthic community will need to improve in a similar manner. If the habitat no longer supports these more sensitive taxa, the stream condition will not be able to improve.

6.8 Condition of Ten Mile Creek

Prior SPA Reports have provided information on year-to-year stream conditions for Ten Mile Creek on a station by station basis. The monitoring data supports the designation of Ten Mile Creek as an extremely environmentally sensitive area of county-wide significance. Base-flows are low in the summer months and the creek is susceptible to low flows from lack of rain. However, even in the driest years, tributaries have continued to flow and to provide cool clean water as refuge for the stream community.

In 2007, State and County fisheries biologists discovered three adult brown trout some distance above the West Old Baltimore Road ford. The trout represented different age classes and did not appear to be hatchery raised. The trout were weighed, measured and returned to the creek. Fisheries biologists returned and conducted a wider survey of the creek but did not find additional trout. It is not known for certain if the three adults found are natural occurring to Ten Mile Creek or not. Regardless of the origin of the trout, the fact that the trout were surviving in Ten Mile Creek are indicative of its excellent water quality.

7. Conclusions and Recommendations

7.1 Water Quality Review Process

In Clarksburg, achieving master plan densities has created problems arriving at cost effective and environmentally effective siting decisions for S&EC and SWM structures. In some cases, SWM quantity structures have had to be sited near environmentally sensitive stream valley buffers or in areas with high water tables because little room was provided in other less environmentally sensitive areas in order to achieve the desired lot yields.

The SPA water quality plan and development review processes should be evaluated to assure that stormwater management and full protection of environmental buffers and other environmentally-sensitive areas are given a higher priority in land development projects in the SPAs. SWM facilities should be sited before or at least concurrently with the other utilities and infrastructure, not after roads and other major infrastructure are in place.

7.2 BMP Water Quality Monitoring Process

Water quality monitoring techniques have changed over the course of the SPA program. Currently, BMP water quality monitoring is the responsibility of the developer with technical oversight provided by DEP. It has been difficult to coordinate and enforce these responsibilities among numerous SPA developer consultants while assuring consistency and good practices.

In the future, developers should be provided an option to have DEP perform the monitoring by paying a BMP monitoring fee. This would allow for more consistency and reduce some of the problems encountered with monitoring.

7.3 Sediment and Erosion Control Improvements

Biological monitoring to date has documented degradation in water quality from construction activities. In order to minimize the effects of construction on water quality, DEP and DPS have agreed to evaluate additional upgrades in S&EC to further protect water quality during construction. Upgrades under consideration include faster conversion from S&EC to SWM, stricter phasing stages of construction to allow greater focus on soil stabilization, limiting the acres of exposed soils, stricter utility S&EC, and limiting of cut and fill activities to retain natural drainage patterns.

7.4 Methods, Facilities and Practices Being Utilized by Applicants as Part of the Water Quality Review Process

The State Stormwater Management Act of 2007 will soon require all jurisdictions to implement Environmental Site Design (ESD) for all new development to the extent practicable, and to modify all relevant codes and regulations as needed to facilitate the application of ESD. The use of ESD is expected to further mitigate watershed-scale environmental impacts from development compared with more traditional strategies. Therefore, ESD including limiting density through clustering or other mechanisms within sensitive environmental areas should be considered as part of a holistic approach to protecting water quality in Ten Mile Creek.

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9. Glossary

- **Aggradation** – A progressive buildup or rising of the channel bed and floodplain due to sediment deposition. http://el.erdc.usace.army.mil/elpubs/pdf/sr01.pdf

- **Base flow –** The portion of the stream discharge that is derived from natural storage (i.e., groundwater outflow and the draining of large lakes and swamps or other sources outside the net rainfall that create surface runoff); discharge sustained in a stream channel, not a result of direct runoff, and without the effects of regulation, diversion, or other works of man. Also called sustaining, normal, ordinary, or groundwater flow.

- **Before-After,Control-Impact (BACI) Design** – An experimental design used to assess environmental impacts. Data is collected **B**efore and **A**fter a change and the data is compared between **C**ontrol and **I**mpacted stations. BACI design is used to account for extraneous factors (such as natural variation). In the Clarksburg SPA, test areas are monitored before and after development and compared to an area where no activity is to occur (Soper's Branch control) and an area where build out is complete and older SWM controls are in place (Germantown/Crystal Rock control).

- **Benthic macroinvertebrate –** Aquatic animals without backbones that dwell on or in the bottom sediments of fresh or salt water that are large enough to see with the naked eye. Examples: clams, crayfish, and a wide variety of worms. http://wmc.ar.nrcs.usda.gov/technical/HHSWR/Geomorphic/glossary.html#B

- **Best Management Practice (BMP) –** Techniques that are most effective in eliminating or reducing the amount of pollution or other detrimental impact to a watershed or wetland.

- **Biological integrity –** The condition of the biological communities (usually benthic macroinvertebrates, and/or fish) of a water body based on a comparison to a reference that is a relatively undisturbed system and represents the best quality to be expected for the eco-region (Boward et al. 1999).

- **Bioretention structure/area** – A stormwater best management practice (BMP) that uses physical, chemical and biological properties of soils, microbes, and plants to filter pollutants from stormwater runoff. Some reduction in stormwater velocity can also be achieved. Bioretention cells are designed to collect, and store stormwater runoff from on –lot impervious areas such as parking lots and allow it to infiltrate into soils. Cells can be incorporated into median strips, parking lot islands and swales.

- **Catchment –** The area of land drained by a stream or stream system.

- **Channel protection volume (Cpv)** – A design criteria which requires 24 hour detention of the one year post-developed, 24 hour storm event for the control of

stream channel erosion.
http://www.mde.state.md.us/assets/document/sedimentstormwater/Glossary.pdf

- **Collector –** Organisms that consume fine pieces of organic matter (e.g., leaf fragments or other material on the stream bottom). http://www.epa.gov/bioindicators/html/invertclass.html

- **Composite sample –** See "Flow-weighted composite sample".

- **Cut and fill** – Process of earth moving by excavating part of an area and using the excavated material for adjacent embankments or fill areas.

- **Degradation** – The lowering of a streambed by scour and erosion.

- **Effluent –** Wastewater--treated or untreated--that flows out of a treatment plant, sewer, or industrial outfall. This term generally refers to wastes discharged into surface waters. http://www.epa.gov/storet/legacy/glossary.htm

- **Embeddedness –** The extent that boulders, larger cobbles, or gravel are surrounded by or covered by fine sediment, such as sands, silts, and clays. http://wmc.ar.nrcs.usda.gov/technical/HHSWR/Geomorphic/glossary.html#E

- **Environmental Overlay Zone –** A zone or district created to conserve natural resources or promote certain types of development. The environmental overlay zones in SPAs aim to protect water quality and quantity and biodiversity. This is accomplished by regulating the amount and location of impervious surfaces in order to maintain groundwater levels, control erosion and allow the ground to filter water naturally, thereby minimizing the temperature and volume of stormwater runoff.

- **Environmentally sensitive areas –** Refers to areas having beneficial features to the natural environment, including but not limited to: steep slopes; habitat for Federal and/or State rare, threatened, and endangered species; 100-year ultimate floodplains; streams; seeps; springs; wetlands, and their buffers: priority forest stands; and other natural features in need of protection.

- **Environmental Site Design (ESD)** – A stormwater management strategy aimed at maintaining or restoring the natural hydrologic functions of a site to achieve natural resource protection objectives and fulfill environmental regulatory requirements. Under this premise, stormwater discharges are to be controlled to the maximum extent practicable and nonstructural BMPs and other better site design techniques must be implemented.

- **Ephemeral stream –** A stream that flows only in direct response to precipitation and whose channel is at all times above the water table. http://el.erdc.usace.army.mil/elpubs/pdf/sr01.pdf

- **Epifaunal substrate –** "Epi" means surface, and "fauna" means animal. Thus, "epifaunal substrate" is structures in the stream (on the stream bed) that provide surfaces on which animals can live In this case, the animals are aquatic invertebrates (such as aquatic insects and other "bugs"). These bugs live on or under cobbles, boulders, logs, and snags, and the many cracks and crevices found in these structures. http://wmc.ar.nrcs.usda.gov/technical/HHSWR/Geomorphic/glossary.html#E

- **Evapotransporation –** The total loss of water by evaporation by a particular area, which is equal to the sum of the water lost to the atmosphere by evaporation from water surfaces; from the wetted surfaces of leaves, trees, stems, soil, and rocks; and that lost by transpiration from plants *(USGS: Watershed Characteristics and Pre-Restoration Surface Water Hydrology of Minebank Run, Bo. County, MD, Water Years (2002-04). http://pubs.usgs.gov/sir/2006/5179/*

- **Filterer** – Suspension feeder; a subcomponent of the group of organisms known as collectors. http://www.epa.gov/bioiweb1/html/invertclass.html

- **First flush –** The first inch of rain over the impervious area creating stormwater with the highest pollutant loading.

- **Flashiness –** The rapid movement of water through urban storm systems into wetland stream(s), followed by a rapid elevation of stream water height, accelerated water flows through the stream, and then a rapid return to low flow water levels. (http://www.urbanhabitats.org/v05n01/wetland_full.html) from: Burns, D., T. Vitvar, J. McDonnell, J. Hassett, J. Duncan, and C. Kendall. 2005. Effects of suburban development on runoff generation in the Croton River basin, New York, USA. *Journal of Hydrology* 311(1–4): 266–281.

- **Flow-weighted composite sample –** A mixed or combined sample that is formed by combining a series of individual and discrete samples at specific intervals and characterized by the flow rate of the discharge.

- **Functional feeding group** – A group of benthic organisms that obtain food in the same fundamental way (e.g., filtering organic particles from the water, scraping algae from rocks, predation). http://www.sra.dst.tx.us/srwmp/glossary/default.asp?term=Functional%20Feeding%20Group

- **Geomorphology** – See "Stream morphology".

- **Grab sample** – A single sample of stormwater representing the concentration of pollutants at a discrete point in time. This method of sampling does not represent an entire storm event.

- **Headwater streams** – These areas are the origins of larger streams and rivers; the health of these larger systems depend upon the condition of the headwater areas. They are small and typically fed by groundwater. Some may be ephemeral/intermittent, drying seasonally or just under drought conditions. They tend not to support a well-balanced fish community.

- **Hydrocarbon** – A compound consisting entirely of hydrogen and carbon. Some types of hydrocarbons are toxic in aquatic systems.

- **Hydrodynamic structure** – (also Hydrodynamic device or separator) is a class of SWM BMPs that treat stormwater by slowing flow to remove sediment and other pollutants. Depending on the device, treatment may be accomplished by swirling the water or through settling and indirect filtration. Due to these processes, Hydrodynamic structures are most effective at treating heavy particulates (such as suspended solids) or "floatables" (such as oil). They are often used as pre-treatment in SPAs and can be either proprietary (trademarked/patented by a corporation) or non-proprietary.

- **Hydrodynamic device** – See "Hydrodynamic structure".

- **Hydrograph** – A graph showing stage, flow, velocity, or other property of water with respect to time. http://water.usgs.gov/wsc/glossary.html#H

- **Hydrology –** The scientific study of the water of the Earth, its occurrence, circulation and distribution, its chemical and physical properties, and its interaction with its environment, including its relationship to living things. http://el.erdc.usace.army.mil/elpubs/pdf/sr01.pdf

- **Imperviousness (Impervious surface or area) –** Impervious surfaces are mainly constructed surfaces - rooftops, sidewalks, roads, and parking lots - covered by impenetrable materials such as asphalt, concrete, brick, and stone. These materials seal surfaces, repel water and prevent precipitation and meltwater from infiltrating soils. Soils compacted by urban development are also highly impervious. http://chesapeake.towson.edu/landscape/impervious/what_imp.asp

- **Index of biotic integrity (IBI)** – A measurement of the aquatic community's structure and function within special protection areas as compared to the aquatic community inhabiting the least impaired reference streams within a specific region.

- **Infiltration** – The movement of water through the soil surface into the soil. http://wmc.ar.nrcs.usda.gov/technical/HHSWR/Geomorphic/glossary.html#E

- **Influent** – Water, wastewater, or other liquid flowing into a reservoir, basin, or treatment plant. http://www.epa.gov/OCEPAterms/iterms.html

- **Irreducible level/concentration** – A limit to how much pollutant removal can be achieved; it is a level in which sediment and nutrient concentrations exist at such low levels that they cannot be reduced further, regardless of how much more surface area, treatment volume, or additional treatment types are provided.

- **Land use** – The way in which land is used, especially in farming and city planning. Examples of categories for land use are forest, agricultural, residential, agricultural, commercial, and urban.

- **Metric** – A measurable characteristic of a biological assemblage; Attributes (metrics) are selected that provide reliable and relevant signals about the biological effects of human activities. http://el.erdc.usace.army.mil/emrrp/emris/emrishelp6/index_of_biological_integrity_tools.htm

- **One-year (1-year) storm** – A storm that has a recurrence interval (or frequency) of one year, approximately 2.6 inches rainfall in 24 hours.

- **Outfall** – The end/outlet of a structural BMP, drain or sewer.

- **Paired catchment (watershed) design** – A study design that pairs drainage areas along similar natural characteristics. Usually one is a "control" and the other is a "test", where a change will occur in the "test" but not the "control". http://www.owp.csus.edu/research/papers/papers/PP014.pdf

- **Pioneer species** – The first species or community to colonize or recolonize a barren or disturbed area. A high proportion of pioneer species indicates an environment that is temporarily unavailable for some species or stressed, thus reflecting lower biotic integrity. This metric was first proposed by Ohio Environmental Protection Agency (1987) to indicate the permanence of the stream habitat. http://mn.water.usgs.gov/redn/rpts/ibi/ibi.htm

- **Pollutant** – Generally, any substance introduced into the environment that adversely affects the usefulness of a resource or the health of humans, animals, or ecosystems. http://www.epa.gov/OCEPAterms/pterms.html

- **Recharge volume (Rev)** – A requirement to have a specific volume of stormwater runoff be recharged into the groundwater in order to reverse the impacts of paved surfaces on groundwater infiltration. The recharge volume is based on the hydrologic soil groups and the amount of impervious area.

- **Riffle** – Shallow rapids in an open stream, where the water surface is broken into waves by obstructions such as shoals or sandbars wholly or partly submerged beneath the water surface. http://dictionary.babylon.com/Riffle#society

- **Riparian/ Riparian zone** – An area of land and vegetation adjacent to a stream that has a direct influence on the stream. This includes woodlands, vegetation, and floodplains.

- **Sediment and Erosion Control (S&EC) –** Sediment and Erosion Controls are installed prior to construction and land disturbance activities to capture and treat sediment-laden runoff. Examples utilized in SPAs include supersilt fences and sediment basins outfitted with additional treatment features.

- **Sedimentation –** Sedimentation is the process of sediment loads entering the stream system and covering the stream bed. Excessive loadings of fine sediment degrades and eliminates riffle and pool habitats available for benthic macroinvertebrates, fish, and stream salamanders. Excessive sediment loads can smother these organisms and their eggs. The movement of sediment can actually scour the stream bottom, accelerate erosion, and diminish bank stability.

- **Stormwater Management (SWM) –** Stormwater Management is utilized on properties after construction is complete to control the quantity and quality of stormwater runoff. Stormwater Management in the SPAs includes treating the first inch of rain over the impervious/developed surface (also known as the "first flush") as quality control and controls stormwater flows by storing the one-year, 24 hour storm (about 2.6 inches of rain). Quality treatment is aimed at minimizing pollutant loadings of receiving streams whereas quantity control functions primarily as maintaining natural stream flows, groundwater infiltration, and bank stability.

- **Shredder –** Organisms that consume coarse organic matter such as leaves. http://www.epa.gov/bioindicators/html/invertclass.html

- **Stream morphology** – The form, shape, or structure of a stream. http://wmc.ar.nrcs.usda.gov/technical/HHSWR/Geomorphic/glossary.html#E

- **Taxa** – The plural form of taxon. A category or group of organisms.

- **Tolerance –** Refers to the organisms ability to tolerate various forms of stress such as low dissolved oxygen levels, high amounts of siltation or salinity, or varying amounts of toxic chemicals. http://www.epa.gov/bioiweb1/html/invertclass.html

- **Total kjeldahl nitrogen (TKN)** – The sum-total of organic and ammonia nitrogen in a sample, determined by the Kjeldahl method.

- **Total Suspended Solids (TSS)** – A measure of the suspended solids in wastewater, effluent, or water bodies, determined by tests for "total suspended non-filterable solids". http://www.epa.gov/OCEPAterms/tterms.html

- **Transfer of Development Rights (TDR)** – A method for protecting land by transferring the "rights to develop" from one area and giving them to another. The TDR program in Montgomery County allows developers to increase residential density in designated areas outside of the Agricultural Reserve to compensate farmers for the land equity lost through the down-zoning that created the Ag. Reserve.

- **Water Quality Inventory** – All persons proposing to disturb land within an SPA, except as provided by law, must submit, for review and approval, a water quality inventory which covers any portion of the project located within the SPA. The inventory includes a stormwater management concept plan, a sediment control concept plan, documentation of impervious areas, additional documentation to show avoidance, minimization, or proposed mitigation for impacts on environmentally sensitive areas, and on priority forest conservation areas as specified in the Planning Board's Environmental Guidelines, and rationale for any proposed encroachment on said areas (per Montgomery County Regulation on Water Quality Review for Development in Designated Special Protection Areas).

- **Water Quality Volume (WQv) –** The volume needed to capture and treat 90% of the average annual stormwater runoff volume equal to 1" times the volumetric runoff coefficient (R_v) times the site area.
http://www.mde.state.md.us/assets/document/sedimentstormwater/Glossary.pdf

- **Water Year –** The U.S. Geological Survey "water year" in reports that deal with surface-water supply is defined as the 12-month period October 1, for any given year through September 30, of the following year. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 1999 is called the "1999" water year.
http://water.usgs.gov/nwc/explain_data.html

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  Landscape Ecology Branch, Research Triangle Park, NC
- U.S. EPA National Risk Management Research Laboratory, Cincinnati, OH
- U.S. EPA Office of Research and Development, Atlanta, GA
- U.S. EPA Environmental Science Center, Ft. Meade, MD

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RELATED DOCUMENTS:

- SPA Annual Report, 2006
- SPA Annual Report, 2005
- SPA Annual Report, 2004
- SPA Annual Report, 2003
- SPA Annual Report, 2002
- SPA Annual Report, 2001
- SPA Annual Report, 2000
- SPA Annual Report, 1999
- SPA Annual Report, 1998
- Clarksburg Conservation Plan
- Piney Branch Conservation Plan
- Upper Paint Branch Conservation Plan

All of the documents cited above are available online in PDF format on our website:
http://www.montgomerycountymd.gov/deptmpl.asp?url=/content/dep/SPA/home.asp
In addition, the Department of Environmental Protection maintains an extensive collection of annual, technical, and general reports, public information factsheets, and related publications. Many are available in both PDF and HTML format, and in some cases, print copies of documents are available. Please contact us for more information.

Department of Environmental Protection/ Montgomery County, Maryland
255 Rockville Pike, Suite 120, Rockville, MD 20850
240.777.7770 fax 240.777.7765
email: dep.askdep@montgomerycountymd.gov